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GAETANO LA RUSSA

Towards an Understanding of Humanoid Robots in eLC Applications

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Abstract

This work is the outcome of inter-disciplinary research in the field of human-robot interaction (HRI) and human behaviour in the usability sector of fundraising. This work specifically correlates to a pilot project called Robo-eLC (eLC is the abbreviation for e-Learning and e-Commerce) which aims to reintroduce, albeit in a technological form, a traditional Finnish money collecting means which consists of anthropomorphic painted wooden statues known as *Vaivaisukot* (*vaivaisukot* in the Finnish language means *Begging Men* and hereafter they will be referred to as Wooden Beggars). These statues, which have a slit on their head or side through which donations could be inserted, were first located at the entrance of Finnish churches in 1649 and were still in use up to a few decades ago. A few examples of these Wooden Beggars can still be viewed across the regions of the west coast of Finland.

The research and development (R&D) of the robotic Robo-eLC extension (i.e. the begging robot, also referred to in various published articles as the *RoboBeggar*) which is, in essence, a replicated and enhanced form of the classical Finnish Wooden Beggar, was driven by these research questions:

Q1) What are the elements that make an eLC-robot a convincing interlocutor to humans?

Q2) What are the robotic embedded ICT elements that contribute to the human understanding of little-known fundraising concepts and ideas?

Q3) What elements pose a threat to the comprehension/learning processes in human - Robo-eLC interactions?

Q4) What are the roles of the cognitive, affective and psycomotive domains in the designing of the Robo-eLC anthropomorphic robot?

The answering of these questions leads to the definition of a set of basic rules which govern the design of efficient fundraising robots in given physical environments and cultural background (contextualised environments) which then, in turn, promote enhanced and pleasant interactions.

The methodological research approach adopted in the quest to seek answers to the main research questions is a mixed quantitative-qualitative case study focusing on the Robo-eLC test cases phenomenon (Johnson & Christensen, 2007).

Some of the test cases' feedback evaluation data of the pilot project Robo-eLC provided information that needed to be triangulated and which, in turn, led to the creation of a non-robotic system, the Touch Screen System (TSS), for testing and comparing the uses of the two systems. An embedded multimedia pillar kiosk with a touch-screen (the InfoKiosk) was driven by similar software used to manage the Graphic User Interface (GUI) and the HRI of the Robo-eLC. The collected data (user-subjective information, observed behaviour information and interviews) from the Robo-eLC and the TSS cases were sketched out and compared in a three-folded analysis study (*cognitive, affective* and *technological*).

The purpose of the three-fold division was to study, compare (where possible) and examine (in the Robo-eLC) the influence and relevancy of robotic features on the quality of the Human Robot Interactions (HRI) and, in the TSS cases, the software influence on the Human Computer (HC) interactions and hence on the users' cognitive processes. An examination of various existing robotic appliances and online donation systems and technologies was conducted in the literature review to evaluate those elements that contribute to the understanding of a generic non-expert user in the use of such appliances.

Finally, as a result of this work, a set of specifications (Chapter 5) is given which were formulated to be used in the design and further development of fund raising robots.

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***

"*Ma se è tutto qui il male! Nelle parole! Abbiamo tutti dentro un mondo di cose; ciascuno un suo mondo di cose! E come possiamo intenderci, signore, se nelle parole ch'io dico metto il senso e il valore delle cose come sono dentro di me; mentre chi le ascolta, inevitabilmente le assume col senso e col valore che hanno per sé, del mondo com'egli l'ha dentro? Crediamo d'intenderci; non c'intendiamo mai!*"

"*But don't you see that the whole trouble lies here. In words, words. Each one of us has within him a whole world of things, each man his own special world. And how can we ever come to an understanding if I put in the words I utter the sense and value of things as I see them; while you who listen to me must inevitably translate them according to the conception of things each one of you has within himself. We think we understand each other, but we never really do!*"

Luigi Pirandello (1867–1936)
From the comedy drama *"Six characters in search of an author"*

Abbreviations

Abbreviation	Description
3D	Three-Dimensional (environment)
AI	Artificial Intelligence
CVE	Collaborative Virtual Environments
DOF	Degree(s) Of Freedom
eLC	e-Learning and e-Commerce
F2F	Face to face
GPS	Global Positioning System
GUI	Graphic User Interface
HCI	Human Computer Interaction
HD	High Definition
HRI	Human Robot Interaction
ICT	Information Communications Technology
IT	Information Technology
MI	Multimodal Interface
NGO	Non Governmental Organisation
NPO	Non Profit Organisation
R&D	Research & Development
SWOT	Strengths, Weaknesses, Opportunities and Threats analysis
TC	Test Case
TSS	Touch Screen System
UBF	User Behaviour Form
UF	User Feedback
UN	United Nations

List of Original Publications

PAPER I. La Russa, G., Sutinen, E. & Cronje J. (2009). Learning paradigms through fundraising systems: The RoboBeggar and the InfoKiosk cases, In: *Advanced Learning.* Publisher InTech, ISBN 978-953-307-010-0, Vienna, Austria. pp. 355-380

PAPER II. La Russa, G., Sutinen E. & Cronje J. (2010). When a robot turns into a totem: The RoboBeggar case, In *E-Learning Experiences and Future*. Publisher InTech, ISBN 978-953-307-092-6, Vienna, Austria. pp. 327-344

PAPER III. La Russa, G., Sutinen, E. & Cronje J. (2008) Avatar Aided e-Learning Fundraising System, *Proceedings of the 8th IEEE International Conference on Advanced Learning Technologies*. IEEE Computer Society, ISBN 978-0-7695-3167-0, 1-5 July 2008, ICALT 2008, Santander, Cantabria, Spain. pp. 246-249

PAPER IV. Prasolova-Førland , E. & La Russa, G. (2005). Virtual humans vs. anthropomorphic robots for education: how can they work together? *Proceedings of Frontiers in Education, an ASEE and IEEE Conference, Pedagogies and Technologies for the Emerging Global Economy.* IEEE Computer Society, ISBN 0-7803-9077-6, 19-22 October 2005, FIE 2005, Indianapolis, Indiana, USA. pp. S3G 26-32

PAPER V. La Russa, G., Ageenko, E. & Karulin Y. (2005). Fund Raising Systems using Robots (Architecture and Behavior Study). *Proceedings of CIRA 2005, the 6th IEEE International Symposium on Computational Intelligence in Robotics and Automation*. IEEE Computer Society, ISBN 0-7803-9355-4, 27-30 June 2005, CIRA 2005, Helsinki University of Technology, Espoo, Finland. pp. 525-530

PAPER VI. La Russa, G. & Marjomaa, E. (2004). Robo-eLC: A robotic adaptive learning appliance. *Proceedings of IADIS International Conference on Cognition and Exploratory Learning in Digital Age*, ISBN 972-98947-7-9, 15-17 December 2004, CELDA 2004, Lisbon, Portugal. pp. 327-334

The above publications have been included at the end of this thesis according to the agreement with the copyright holders.

Author’s contribution to the publications

I am the main author of PAPERS I, II and III which describe the research approach, the test cases and their environments, the sociological background of the research, the outcomes of the tests and the analysis of the collected data. I am the co-author of PAPER IV in which the feasibility of integrating Collaborative Virtual Environments (CVEs) and the Robo-eLC is analysed. I contributed to PAPER IV by describing the feasibility and role that the Robo-eLC could play in collaborative learning environments towards raising human social awareness in situated and collaborative 3D virtual environments. I am also the co-author of PAPER V in which robotic architecture and behaviour are described. My contribution to PAPER V is the description of robotic behaviour and interactivity in HRI, its e-learning modularity and impact on users. PAPER VI, which describes the learning multimodal interface of the Robo-eLC and its correlation to the users’ cognitive behaviour, was also co-authored by me. In PAPER VI my contribution lies in the description of the architecture and multimodal aspects of the Robo-eLC, the adopted inter-disciplinary approach to the study and the feedback analysis related to users’ cognitive learning behaviour.

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1 Introduction

This research originated from concerns expressed by Finnish third sector organisations (voluntary and non-profit organisations) regarding their efficiency in reaching potential donors via the use of ICT, and specific IT embedded collecting means, to aid distressed populations and provide necessary services. After considering the historical and cultural background, it was decided to revive a traditional Finnish collecting system based on wooden statues (known in Finnish as Vaivaisukot, the "Wooden Beggars") which represent people begging. Based upon these wooden statues, a robotic system for combined learning and donation activities (a robotic eLC, hence the pilot project Robo-eLC) was devised. In a more general sense, the research attempted to look at the motivations which people would find acceptable when dealing with interacting artefacts and consequently also investigate those elements that would support such interactions or which might otherwise hamper the use of embedded ICT in fundraising activities. The known problematics related to the digital divide (Norris, 2003; Zhang et al., 2009; Zickuhr & Smith, 2012), technophobia/digiphobia (Gilbert et al., 2003; Juutinen, 2011) and the natural cultural and educational hindrances known to impede the developing of any efficient fundraising systems were also taken into account. Studies were made to avoid or diminish the occurrences of these negative factors as well as in consideration of Norman's (2002) work on the importance of a user-centred technological design. Acknowledging the role that affections and cognition play when they work together (Stubbs et al., 2005; Miloseva & Lehtonen, 2006), the proposed fundraising system and its interactions had to be at the core of a design where a user's satisfactory learning experience would occur alongside emotional self-gratification.

Short historical and geographical excursus

In the first half of the seventeenth century the kingdom of Sweden, while taking part in the Thirty Years' War of 1618-1648 (Robets, 1953; Robets, 1973), was devastated by a prolonged famine. Queen Christina of Sweden (1926-1689), faced with a state treasury depleted by war expenses, commanded in 1649 that Wooden Beggar statues be placed in church entrances to collect money for the poor (°Saariholma (a), 2001). At this time Finland was a consolidated part of the Swedish kingdom and the royal order was thus carried out in this territory as well. It is not known why most of the remaining/surviving Wooden Beggars are located in the Ostrobothnia region of Finland which is along the western coast. A few examples can also be found in southern and eastern Finland.

Please note: Pictures that are taken from public accessible webpages and used in this thesis for explanatory, clarifying and sampling purposes are referred to within the text by the symbol * followed by a cardinal number. The related links are given at the end of all the references (the bottom of Non-Academic References). References have been divided into two groups: *Academic References* highlights those references that are of an academic accredited level or value (Journal papers, Conference papers, online academic published papers, books and so on) and *Non-Academic References* refers to those references that are not deemed to be on an academic level but which still come from trustworthy sources (informative newspaper articles, evaluation or reporting papers, technical papers, online verifiable data and so forth). These latter references are marked in the text by the symbol ° placed before the names or acronyms.

Figure 1 shows two surviving examples of wooden begging statues. These statues have slits through which donors are able to push coins. They continued to be used during the prolonged Russian domination of Finland (autonomous Grand Duchy 1808-1917) and were, until a few decades ago, quite a common sight in the west of Finland where people still deposited charitable donations in them. One hundred and eight examples of these wooden beggar statues are currently extant (Santaholma, 2001; °Wiki (a), 2013). Of these only one, in the Lutheran Church at Soini, has female features (°Etelämäki, 2000; °Fides, 2002).

Figure 1: Two Wooden Beggars (*Vaivaisukot* in Finnish) (*001)

While the traditional Wooden Beggar had a clear social and historical value, dating back to the seventeenth century, and which remains well known in recent decades, its technological counterpart (the robotic Robo-eLC) was from its very inception perceived as very challenging due to its interdisciplinary and multipurpose aspects. While computer science would provide the backbone programme to support the interactions between the potential donors and the new begging statue (the RoboBeggar), it had to be defined with a scientific approach and methodology that would drive the whole research study and this thesis outcome.

Robots and their role in human society

It was the Czech writer, Karel Čapek, who in 1920 introduced the word robot[1] in his play R.U.R. (Rossum's Universal Robots)[2] to describe artificial people created to serve (for *R.U.R.* play see Čapek, 2004). Despite the fact that the original reference to "*robots*" in the play would be closer to modern androids and clones, the word soon became the common term used to describe machines (even though in the beginning mainly *anthropomorphic*[3] – i.e. resembling human form, being also called humanoid[4] robots) capable of conducting autonomous works to reach specific goals. The imagination of the public was soon awakened by the introduction of intelligent and autonomous robots in literature and the movie industry[5] (°Wiki (b)(c)(d)(e)(f), 2013). Two milestones in literature are "*Runaround*" (Asimov, 1942) and "*I, Robot*" (Asimov, 1950).

When I use the term *humanoid robot* in this work, I am referring to a robot that, in its appearance and shape, resembles a human. I ascribe to the term *anthropomorphic robot* a higher human similarity or resemblance (where in addition to the exterior human similarity a robotic *character* and *behaviour* resembling that of a human can be individuated) and therefore, strictly speaking, anthropomorphic robots are *more* human-like than the humanoid robots that rely more on their human-like appearance instead. In general, the two terms could refer to the same robot (without an error being made) when they refer to different aspects of the robot itself. Whenever I cite others' work, I maintain their use of the terminology.

Interest regarding robots, both in academic research and industry applications, has been developing in many differentiated sectors over the last few decades. The fact

[1] The word *robot* is derived from *robota*, which means "drudgery" (hard boring work) in Czech and "work" in Slovak.
[2] Written in 1920; first performed in Czechoslovakia in 1921; performed in New York in 1922; the first English edition published in 1923.
[3] Anthropomorphic refers to having human characteristics or ascribing to human attributes. The word derives from the Greek word ánthrōpos, meaning *human*, and morphē meaning *shape* or *form.*
[4] The term humanoid is a combination of the English word *human* and the Greek based stem -oid that means *resembling* or *likeness.*
[5] The robot named Maria in the movie "Metropolis" (1927) gave rise to speculation regarding opportunities or possibilities to depict, design and create humanoid robots.

that robots are generally expected to be human-like (android[6] or gynoid[7]) is mainly a consequence of the science fictional approach and the influence which this has had on people's imagination. However, robots tend to be classified according to their purpose, intelligence, mechanical structure, efficient deployed power and, last but not least, their reliability. The work conducted in this thesis research has forged in the direction of establishing a basic *ballast* (in the sense of stability and equilibrium in HRI) that can be defined as the stability and partnership reliability of the robot as perceived by humans. The ballast is defined by the elements (visual, audial and tactile) of the robotic physical structure, its intelligence and its interactive means (the tools and paths that are used in its interaction with the users).

Computer Science… but not only

The traditional approach of computer science towards users' cognitive processes and the development of skills in novice users is often considered as a matter of problem solving, a thinking-understanding correlation in the domain of mathematics (Dzbor, 1999). Researchers have often focused their attention on how experts and novices' understanding differs when looking at a comparison of behaviours and skills and consequently researching solutions for bridging the existing gaps. Cognitive science has recently extended the concept of internal mental structures to include the interactions (Sauter, 1999) that take place between a person and the environment (a combination of the virtual and the real ones) (Beer et al., 1999). Some attempts to take users' behaviours (i.e. the expression of mental structures) into consideration have been made when dealing with the design of advanced learning environments.

Certain physical representations can be used; not only to describe objects but also to convey concepts (in which case we refer to cognitive stimulating elements or associative ideas). These representations are capable of keeping a sort of events' history of the environment and to interact with the users, which in turn stimulates the development of new concepts. Thinking and understanding have a natural concrete basis in the realistic and/or imaginary perception of the cognitive data. Representations are nothing less than people's concrete mental models and are fundamental to human thought processes (Gentner & Stevens, 1983). In addition, it must be noted that mental construction and manipulation of concrete mental models are always influenced by already existing cognitive models. Many of these

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[6]Android (from the Greek andr-, meaning "*man, male*", and the suffix -eides, used to mean "*of the species; alike*") is a robot made to resemble a human male.
[7] Gynoid (from Greek gynē-, meaning "*woman, feminine*" and the suffix -eides, used to mean "*of the species; alike*") is a robot made to resemble a human female.

concepts are implemented in computer science when dealing with human-computer interactions for example or learning environments and problem solving.

A computer-based learning environment can facilitate the construction and use of mental models but in many cases it requires a physical convener to bridge the gap between abstract concepts and concrete mental models (Gentner & Stevens, 1983). It is important to remark that cognition is not a purely mental process but an intellectual system that includes the individual's perception of own context and the available tools. Computer-embedded learning environments, like robots, could take into account the role of the physical domain and facilitate the learning process of their interacting human users because of the physical concretisation of abstract thinking. Visually concrete objects can be linked to formal and abstract concepts, thus triggering a more dynamic learning process. Learning environments are situated places where learning occurs (Dillernbourg et al., 2002). Learning environments can be physical or virtual in nature or a combination of the two (PAPER IV). A robot can be considered a learning environment if it possesses teaching features and is able to combine them with its own physical situated characteristics (Section 4.3), thus becoming a Multimodal Interface. The Robo-eLC possessed an users' interacting learning modularity (see Section 4.3) and physical features (see Section 3.2 and Section 4.2) capable of conveying meaningful communication to help users to concretise and strengthen their own perception and cognition in the learning processes (PAPER VI). The Robo-eLC combined its virtual and physical parts into one to create cohesive learning environment.

Pfeifer (1996) divides computer science into core computer science (the very coding and algorithm writing and what is strictly pertinent to them) and applied computer science (computer science compiling applied to real life via the integration of multidisciplinary know-how, including systems' environmental work conditions and usage and human centred factors related to psychology, cognitive science and learning behaviours). Glass et al. (2004) wrote a detailed analysis of the three main computing disciplines (computer science, software engineering and information systems) based on 1 485 journal papers which highlighted the interrelationship that exists within these disciplines, their research approaches, their research methods and the reference fields to which they relate. Tedre (Tedre, 2006) shows that computer science should extend to incorporate elements from other fields such as sociology, history, anthropology and philosophy as this amelioration will lead to a truly contextualised and developing science. Computer scientists have a sociological responsibility in the design and development of their tools (codes, algorithms, software etc. in connection or not with other related fields that should contribute to the quality of the final work results). The philosophical strength and wide approach set forth by Tedre's thesis highlights the vast amount of work needed to justify and/or motivate research choices. This thesis work intends to move beyond a traditional computer science work as it deals with human-robot interaction (HRI) and learning processes from a sociological perspective as well.

Case Study Research

A case study is a particularistic, heuristic, intensive, holistic description and analysis of a single entity, phenomenon or social unit in a bounded system where the number of people, data and time involved in the study are limited (Merriam, 1998). Case studies are adopted to investigate single or multiple cases according to quantitative, qualitative or mixed methodologies in order to generalise and expand theories (Yin, 1993).

This thesis work intends to present the discovered reasons and circumstances for the successes or failures of the anthropomorphic robot Robo-eLC and also to formulate design guidelines to help improve the design and development of future fundraising robots. The Robo-eLC is a robotic application meant for e-learning and fundraising which triggers learning behaviours (besides PAPER I-VI, other reference material can be found in La Russa et al., 2004). Test cases on human-robot interaction have been conducted and then analysed. The analysis data and extrapolated information are compared to other existing cases of human-machine interaction and a brief overview of on-going research and development sectors of educative robots is given. Finally, the obtained results of the Robo-eLC test cases are compared to the results obtained by a non-robotic system. The InfoKiosk, a Touch Screen System (TSS) integrated into an ICT pillar, had a multimedia interface similar to that of the Robo-eLC. The comparison of the anthropomorphic robot cases and the InfoKiosk case provide and confirm relevant information regarding human-robot interaction and its conditioning factors. Consequently, this information is combined into a set of guidelines for the design of the anthropomorphic robots.

Randolph states that "*the goals of a case study are to develop an in-depth understanding of a case, or multiple cases, and to gain insight into the interaction between the phenomenon and the case*". He further adds that in phenomenological research the study object is a *lived experience* (McCarthy & Wright, 2004) or phenomenon and researchers collect their data through interviews with the people who have been involved in that experience (Randolph, 2007). McCarthy and

Wright (2004) comment that *"in recent years there has been a perceptible shift in nomenclature toward Interaction Design or User Experience Design when referring to relationships between people and interactive technologies. This reflects a broadening of focus from computers to a wide range of interactive technologies and from work-related tasks to lived experience*". In this thesis the mixed *qualitative-quantitative research method*, which involves the why and how questions and answers regarding the viability of replicating the Wooden Beggar and enhancing it in the form of a digitally controlled humanoid robot, is used to conduct the *experimental research* (Johnson & Christensen, 2007) and to help find the answers to the following questions:

Q1) What are the elements that make an eLC-robot a convincing interlocutor to humans? Answering this question brings about a new approach to and novel solutions in the sector of fundraising humanoid robots towards the creation of more individualistic interactions between humans and robots (behaviouristic[8] robots). This is achieved via a literature review of similar appliances (robots or multimodal appliances and online interactive services), the creation of event and donation contextualised test cases (both Robo-eLC and InfoKiosk), the analysis and evaluations of the test cases' feedback and Focus Group interviews draw real patterns for human-robot interactions. The publicised work contained in PAPER I-VI provide the main material for tackling this issue which is further dealt with in Chapters 2, 3, 4, 5 and 6.

Q2) What are the robotic embedded ICT elements that contribute to the human understanding of poorly known fundraising concepts and ideas? Answering this question highlights the benefit that can be gained from existing technology and the proper and efficient re-organisation of the robotic interface multimodal information. This is partly achieved through a literature review with a special focus on the educational, sociological and cognitive impact of interacting multimodal appliances and partly by an analysis of test cases' data. PAPER I, II, IV and VI in conjunction with Chapters 2, 4, 5 and 6 provide answers to this issue.

Q3) What elements pose a threat to the comprehension/learning processes in human - Robo-eLC interactions? When answering this question one is bound to users' real needs in relation to robotic services (i.e. e-learning and e-commerce related services) and how these interactions are constructed and developed. This information is obtained from users' behavioural analysis, the data from test cases as well as metadata analysis that include user-subjective information, observed

[8] *Behaviouristic* as related or relating to behaviourism.

information and Focus Group interviews. PAPER I and V as well as Chapters 2, 5 and 6 provide answers to this question.

Q4) What are the roles of the cognitive, affective and psycomotive domains in the designing of the Robo-eLC anthropomorphic robot? When answering this question three paradigms in stimuli interaction and the relative acceptance of the Robo-eLC in view of design principles are defined. This triune approach adds to the understanding of users' learning in relation to physical communication, pleasure and cognitive processes. The literature review and analysis of the feedback from test cases provide evidence that these factors do indeed stimulate or impoverish users' human-robot interactions. The users' subjective and objective behaviours (their assessments and statements as well as their observed behaviours) are at the core of the analyses (user centred approach) and the practical elements are also highlighted. PAPERS I, III, IV and VI as well as Chapters 2, 5 and 6 address this question.

The analysis of the test cases' data in a threefold paralleled examination (Q4) takes into account the *Cognitive Analysis*, the *Affective Analysis* and the *Technological Analysis*. Test case data, relating to the Robo-eLC cases, are compared to those of the Touch Screen System of the InfoKiosk. These four research questions are finally dealt with and summarised in Chapters 5 and 6 in an effort to define a set of specifications and rules which could, in the future, be used in the design of attractive fundraising robots.

SWOT Analysis

A SWOT Analysis (Strengths, Weaknesses, Opportunities and Threats) is generally considered a good analysis tool when assessing a complex project or plan's existing internal and external resources as well as its deficiencies. This analysis thus provides a realistic overview as well as a sound starting point from which to build a planning strategy (Hill & Westbrook, 1997; Koch, 2000; Koch, 2001). Below is the SWOT that was conducted at the start of the research work. For a schema representation of a SWOT Analysis see Figure 2.

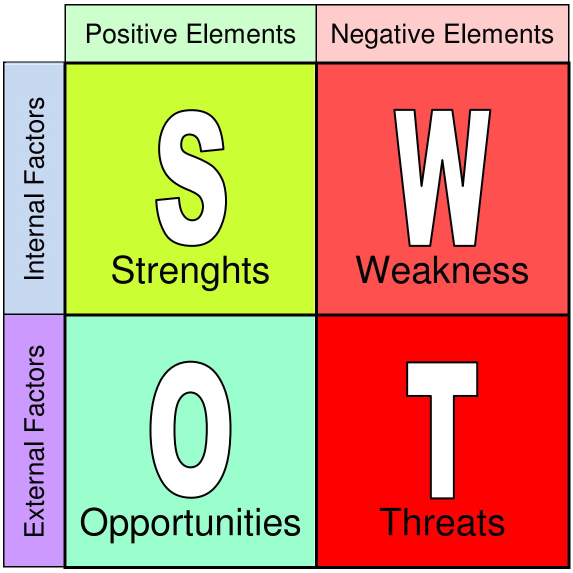


Figure 2. The SWOT diagram

Strengths (internal). The School of Computing of the University of Eastern Finland has been involved in multidisciplinary research for many years (from 1999 onwards) with a department dedicated to Educational Technologies and its application to e-learning. Researchers in this department hail from different countries and often possess academic qualifications in fields which vary from social to natural sciences. Cooperation and inter-participation between projects and researches is a common practice in the department. Valuable department computer scientists, cognitive scientists and pedagogists have all, albeit at various stages in this thesis research, participated to the body of knowledge. My specific educational background in structural engineering and expertise in public relations, pedagogy (as a High School teacher), cognitive science and human interactions count among the assets. The fact that I have lived in Finland for many years, that I am proficient in the native language and also possess an understanding of the Finnish cultural background served me well in the creation and execution of the tailored test cases.

Weaknesses (internal). Humanoid robotics is a new field in our department and the physical construction of the robot was started from scratch: this included the shell design and the assembly of the motion elements, the skin colouring and dressing of the robot - all were created from the very beginning while constantly considering the expected test cases. Practical and technical materials and skills had to be acquired or sourced from somewhere else than the University of Eastern Finland. The cooperation afforded by the local professional schools for mechanics, plastics and metal works (Pohjois-Karjalan Aikuisopisto, Pohjois-Karjalan Ammattiopisto and Pohjois-Karjalan Ammattikorkeakoulu) helped in the sourcing of the necessary materials and even in the constructing of hardware parts for the designed robot.

Opportunities (external). For many years, The School of Computing of the University of Eastern Finland has had quite an extensive cooperation and research activities network with universities and research centres from across the globe. Most of these activities, especially those relating to the sector of educational technologies, are in IT and ICT in education. E-learning, sociology, psychology, educational technologies, robotics in education and pedagogy are among the strong fields of cooperation for research and development (R&D) investment of the sector. Contacts with local and national authorities (municipal offices, funding organisations etc.) and cooperation with church organisations and NGOs (charities, cancer fighting institutions and mission organisations) has been solid and supportive, which has helped in the sourcing of data and information necessary for the design of test cases. The planning of tests events, also those set in remote locations, benefitted greatly from this.

Threats (external). The voluntary use of the Robo-eLC and the TSS (in public and semi-public localities) could add an element of risk of failure to the test cases due to technophobia/digiphobia. The possible malfunction of the two learning systems could also hinder users from trusting the systems' functionalities. Possible physical damage to the systems by users had to be prevented. All these elements were solved by conducting an information campaign regarding the use of fundraising systems and providing professional supervision during the use of said systems (whenever it was possible). Where it was not feasible to supervise the interaction, a local desk officer was charged with the system's basic maintenance and I was frequently informed as to its status. The interface software was also designed to allow for mechanical start and shut down by simply plugging in or unplugging the electricity (which eventually had to done throughout the duration of one test case). Winston Churchill remarked that "*a pessimist sees the difficulty in every opportunity; an optimist sees the opportunity in every difficulty*" (°Moncur, 1998).

Structure of the Thesis

This thesis summarises the research work outcomes described in the annexed and published papers. The papers are referred to as PAPER I, II, III, IV, V and VI and are listed in the prologue. The papers are included starting on page157.

Chapter 1 (Introduction) describes the motivations and research perspectives of the original approach which were endorsed and maintained throughout the R&D. The literature review, contained in Chapter 2, has been sub-divided into three main divisions which present the problems which exist in the Third Sector (2.1), the *state of the art* robotics sectors (2.2) and the relevant scientific studies related or connected to HRI (2.3). Chapter 3 presents the research methodology background to this thesis (3.1) and describes in detail the execution of said methodology for this work (3.2). The Research Questions and their pragmatic handling are presented at the end of Chapter 3. The physical Robo-eLC prototype and its main components are described in 3.2.2 and 3.2.3. The software, architecture and the modularity of the Robo-eLC are described in Chapter 4. Chapter 5 presents the results of this research and Chapter 6 offers concluding remarks and recommendations. References 1 lists those references that are of an academically accredited level or value. References 2 lists those references which are not of academic level but still originate from trustworthy sources and are also fundamental to an understanding of the sectorial developing situations wherein robots can also be grouped (these references are informative newspaper articles, evaluation or reporting papers, technical papers, online verifiable data and so forth).

2 Background and Literature Review

The literature which is referred to in this thesis was chosen on the basis of the authors' competences, item relevancy and pertinence, quality cross-referencing (i.e. other field authors refer to them as relevant sources) and in some cases as newly published materials or disclosed strategies in robotics (in research and commerce). The presented material intends to provide an understanding of the existing problems and exigencies in fundraising for the third sector (Section 2.1), an overview on R&D in robotics (Section 2.2) and a view of human robot interactions (Section 2.3). This chapter provides the background overview in terms of scientific and humanistic fields that support this study approach hence raising the motivations for its fulfilment. The motivations for using the employed methodology are further discussed in the following chapter, Research Method. Due to the complexity and extent of the third sector in the world and for reasons of simplicity, a special focus on the third sector in the UK, USA and the European Union as a whole is evident.

2.1 Fundraising for the Third Sector

Kelly (1998) states that "*fund raising is a management function that identifies, builds, and maintains relationships between charitable organizations and donors for the purpose of exchanging resources to attain philanthropic goals that benefit others, as well as those involved in the exchange. More simply...Fund raising is the management of relationships between a charitable organization and its donor publics*". During the past few decades, marketing and communication specialists have paid increasing attention to the possibilities inherent in fundraising by means of those systems mentioned above. At the heart of this activity have been attempts to define reliable criteria for soliciting strategies (Hart et al., 2005; Patterson & Radtke, 2009). During this same period, a large number of field studies and reports have been sponsored by fundraising organisations and other interested parties in the hope of identifying those conditions which promote or hinder fundraising activities, as well as related trends, needs and sector investments and the expectations and expenditures that define this field of research (°Chouinard, 2011; °MacLaughlin et al., 2012; Longfield, 2012; °Giving USA, 2012, °NRC, 2012; °Corbett, 2012).

The efficiency and amounts collected by fundraising organisations vary for each country. According to The °Charity Commission of England, which provides a financial overview of charities in England and Wales (°Facts & Figures, 2012), the annual growth rate in fundraising between March and December 2012 was 2.7% (in comparison the growth rate between September 2008 and March 2009 was

6.8%). Although this figure has shown a decreasing tendency in relative percentage, it is still in keeping with the total amount of money (UK£ 58.480 against 49.943 billion in 2009) collected throughout the world by 162 098 charitable and humanitarian organisations by 31 March 2012 (the cut-off date for this data). According to *Giving USA* (°Giving USA, 2012) giving in the United States of America reached US$ 298.42 billion in 2011[9] while donations in 2008 (°ACB, 2009; °Bond, 2009) were US$ 307.65 billion (which already showed a drop of 2% from the total amount collected in the previous year). The total giving, as a percentage of the USA Gross Domestic Product, has during the last 10 years remained above 2% shared among over 1 million non-profit organisations (in 2010 the number of non-profit organisations were 1.280.000 while in 2011 they had decreased of over 200.000) (°Giving USA, 2012). Although the use of mobile phones for fundraising in the USA (also called *mobile fundraising*) lags behind in the amount collected if compared to more traditional methods of donation solicitation, it is nevertheless growing (from a low 0.0016% of the total amount that was donated as a result of formal fundraising activities in the United States in 2007 and 2008) (Hiley, 2009) due to the awareness of third sector specialists and strategy decision makers (°ICTforesight, 2007; °MacLaughlin, 2013). Because of the large amounts of money involved in the third sector, many organisations provide fundraising training courses to teach and train personnel in this activity (°Institute of Fundraising, 2013; °Directory of Social Change, 2013; °Weisman, 2013; °Foundation Center, 2013). Fundraising organisations do experience management problems with regard to their reserves policies and the degree of transparency with which they operate and attempts are being made to rectify this (°Ainsworth, 2008; °ECNL, 2009; °Charity Commission, 2013). The debate continues and it appears as if fundraising organisations find it difficult to adapt to becoming more transparent and open to external probing of their resources and management policies. This is illustrated from the position expressed by the umbrella organisation, European Foundation Centre, to the European Commission (°EFC, 2009).

In recent years, strong debates have been raised regarding the accountabilities of soliciting methods and ethical approaches. A NPOs' watchdog investigation in the UK on F2F soliciting exposed "chugging methods" that promptly raised harsh reactions by NPOs (°Booth, 2008; °Lake, 2008; °Harvey, 2008). The controversy surrounding the use of wrong approaches in F2F donation is a worthwhile issue and, as °Harris (2012) states, "*even if you believe in some kind of philanthropic*

9 According to the Atlas of Giving (°Atlas, 2012) in 2011, charitable giving in the USA reached US$345.91 billion. The US$47.49 billion difference might be due to goal/source exclusion counting methods.

ideal, chuggers seem to now be in danger of miring charities in controversy and bad feeling. For all the cash-raising feats they have managed in the past, charities may wonder: what happens when your treasured brand becomes equated with nuisance, insincerity and rather questionable business practices".

It is worth noting that "cold" door-to-door fundraising techniques are still widely used by many organisations and, according to the Public Fundraising Regulatory Association (PFRA), this method of fundraising can still produce excellent results (°Lake, 2012; °Jordan, 2009; °Andalo, 2012; °Institute of Fundraising, 2012). Ironically, it is the continued use of this traditional door-to-door technique (which is regarded as a tried-and-tested method that delivers good results) that accounts for the less-than-expected amount of interest in Internet fundraising methods and various other online and offline techniques (°Lake, 2009).

2.1.1 Needs of the fundraising sector: money and professionalism

The needs of the fundraising sector cannot only be quantified in terms of the ultimate purposes of fundraising or the means that are used to pursue fund solicitation. The very nature of the fundraising organisations themselves and the degree of efficiency with which they operate are also matters of great concern to these organisations (°Lewis, 2012). Most fundraising and non-profit organisations tend to use their own resources and expertise to reach potential donors and they base their strategies mainly on their own past successes and failures. For most fundraisers past successes dictate future methods and they thus tend to approach the same donors and use the same methods of soliciting – thereby forfeiting opportunities for improvement, expansion and increased efficiency that are currently being offered by more advanced technological systems (Hart et al., 2005; °Dresner, 2013) and the advice of experts in this field (Patterson & Radtke, 2009). Studies have even shown that some organisations forfeit the advantages that could be accrued from the publication of budgets and annual reports. These reports are valuable because they increase the organisation's transparency and trustworthiness by providing certified information about its operations and proposed future strategies (°Ainsworth, 2008). Third sector organisations' obligation to report on their finances with a transparent description of their activities is addressed as a means of increasing credibility and thus improving their impact on donors and the public as appears in in-depth studies by °Addarii et al. (2009).

While it is impossible to exactly quantify the total amount of money that is needed by non-profit organisations that intervene in critical situations and ameliorate a variety of urgent problems in the fields of health, social services, culture, law, politics, humanitarian aid, philanthropy, religion and the environment (Simon, 1995), it is nevertheless possible to define how much capital has been expended and to what extent the annual amounts raised have varied from year to year (°Giving USA, 2012). Reductions in amounts raised from year to year place an enormous strain on non-profit organisations and make it very difficult for them to maintain the quality and scope of their operations from one year to the next with dwindling resources. It is interesting to note that annual reductions in the amount of money collected through fundraising affect mainly the e-fundraising sector (electronic fundraising that is based on Internet services or mobile systems). These (electronic) forms of fundraising have suffered far more from reductions in expected targets during the last years than the traditional face-to-face (or door-to-door) fundraising methods (°Lewis, 2012; °Lake, 2012). It has been hypothesised that face-to-face fundraising methods have been far more effective in raising more funds for their organisations because of their consistent investment in the training and preparation of volunteer fundraisers (°Jordan, 2009).

In 2003, the United Nations (°UN a, 2003) published guidelines recommending certain standards and norms for the development and publication of data emanating from non-profit organisations. This report includes recommendations regarding the necessity for detailed data about non-profit organisations, their activities and how volunteer activity should be divided to reflect national components. Although the data in this handbook is over a decade old, it nevertheless offers essential insights into the way in which voluntary work should be organised. In Finland, from 1995 to 1997, the percentage of the population that made voluntary donations was 33%. The average for the European Union was 32%, and the average for the United States of America was 49% of the population (°UN b, 2003).

Experts and analysts in this field agree that non-profit organisations have been aggressively positioning themselves in commercial settings (Weisbrod, 2000) because the benefits they might accrue in doing so have not escaped their notice. The advantages of being present and active in commercial environments and the advantages which might ensue when fundraising organisations transform themselves from *non-profit* organisations into *profit-making* organisations that function in competition with traditional businesses and shops, have now been widely accepted (°ThirdSector, 2009; °Rickey et al., 2011). Whether fundraising will remain at the high levels achieved in previous years by non-profit organisations once they become thoroughly commercialised (and so possibly less deserving of support in the eyes of their established donors) remains to be seen (°Niven, 2012).

Administrative costs and the costs of promoting and expanding fundraising activities can exert a decisive effect on the organisational structure of fundraising organisations. The running costs of very large non-profit organisations in the

United Kingdom vary between 23% and 25% of their total income. Unicef UK spent 25% of its income in 2008 on fundraising, sales and administration costs (°Unicef UK, 2009) and 24% in 2011 (°Unicef UK, 2012). In contrast to this the British Red Cross spent 30.65% in 2008 (°BRC, 2009) and 37.6% in 2011 (°BRC, 2012). In the same periods the Unicef USF (United States Fund) used 12% in 2008 (°Unicef USF, 2009) and 11.5% in 2011 (°Unicef USA, 2012) and the American Red Cross used 58.4% in 2008 (°ARC, 2009) and 50.6% in 2011 (°ARC, 2011). Bradley et al. estimated that the average administrative and running costs for similar fundraising organisations in the United States is about 18% (Bradley et al., 2003) and that such costs could be reduced by 5-10%, with an equivalent in total savings for all such organisations of up to $100bn. The debate on how to affect savings is certainly not over yet. Prakash and Gugerty (2010) show that there is ample scope for internal structural reforms to systems that many organisations could carry out without any outside assistance. This would substantially reduce costs and increase efficiency but similarly (and eventually due to a lack of self-reform) there is room for legislators to intervene and set standards which non-profit organisations would need to follow. °Keating (2006) addresses the way in which fundraising organisations behave noting that they withhold data by selectively choosing what information to disclose to specific counterparts. He further stresses the need for minimal level requirements as regards the reporting and publishing of organisational data.

Finally, according to the report entitled *Toward a New Asian Development Bank in a New Asia* from the Asian Development Bank (Panitchpakdi et al., 2007), 90% of the population in countries that are now reasonably stable will experience widespread severe poverty by 2020. This report acts as a warning to donors to prepare themselves for the advent of these conditions. The United Nations report entitled *The Millennium Development Goals Report 2008* (°UN, 2008) emphasises that the fight against poverty in developing countries require not only political will and determination but also adequate funding in the long term. Thus far the fight against *severe* poverty has worked and in 2010, 5 years in advance of the set deadline, the goal to half this condition had been reached (°UN, 2012). In its 2008 report the United Nations emphasised that both private and non-governmental organisations play a crucial role in the campaign against poverty and recognised that the actual amounts collected were still inadequate for the purposes for which they were needed (°UN, 2008).

The revenue collected by fundraising organisations has to be adequate to finance the following activities, processes and assets:

1) Logistics
2) Administration
3) Technology
4) Personnel training
5) Budgeting
6) Investment goals

The Benton Foundation published a guideline paper for non-profit organisations to aid them in defining weak points in their use and integration of technology (°NPower, 2002). The paper states that "*creating a technologically literate organization is a continuous, iterative process*" and therefore any actual action to cope with a present ICT problem should always be followed up with a proper management strategy update. Merkel et al. (2007) state that "*technology plays an important role in nonprofit organizations, enabling them to advertise services, communicate their mission, and recruit volunteers. Despite this potential, there is evidence that nonprofits often do not have a comprehensive strategy for incorporating technologies such as email or a website into their organization*".

Backer et al. warn non-profit organisations that if they wish to retain the advantages of integrated ICT in their internal management systems and procedures, periodic revisions are obligatory. They state that "*technological changes have produced mixed results for nonprofits. Technology has broadened funding sources for some nonprofits and restricted funding options for others*" and that "*organizations that lack the technological infrastructure to participate or the name recognition to attract online donations may be left out of this new fundraising approach. Computer-based fundraising also raises the question of what role federated campaigns such as the United Way will play in the future*". My interests, for the purposes of this thesis and for future research, are centred on the technology (the need to devise and develop additional forms of fundraising technology that will empower the work of fundraisers) and investment goals (the need to support current modes of fundraising by integrating them with various tried-and-tested procedures of e-learning).

2.1.2 The UN and some global reference figures for fundraising

According to the United Nations Report publications, entitled *The Millennium Development Goals Report 2008* and *2011* (°UN, 2008; °UN, 2011), in 2007 there were a total number of 42 million (in 2011 this figure was augmented to 42.5 million) displaced people throughout the world whose lives have been disrupted by various kinds of conflict and persecution. In 2007 The United Nations itself was caring for 16 million of these refugees (15.2 million in 2011). When one examines what these publications have to say about the employment rates outside the agricultural sector in various regions of the world, interesting figures emerge. In the developing regions of North Africa, Western Asia and Southern Asia, the employed female population stands at only 22%, 25% and 34% respectively in 2007 and 19%, 19% and 20% in 2010. As opposed to this, the male employment rate in 2007 is 70% (for the countries of North Africa and Western Asia) and 78% (for the countries of Southern Asia). These figures make it clear that the employment ratio of females in these regions is, on average, over 40 points lower than that of men in the same countries, while there is, on average, a difference of 20 points between male and female employment rates if one combines the figures for the remaining developing regions. The reports note that the creation of jobs, which are specifically reserved for women and which are supported by local existing institutions, would increase their employment rate and that this would enable these women to meet their family responsibilities more effectively than they do at present. These recommendations remain a focus point for developing countries.

One in five workers from developing countries currently live in extreme poverty because of low salaries and because about half of the jobs which they do have are temporary, ad hoc, transitory, frequently exploitative and without guarantees or state regulation of any kind. Working poverty has decreased in the last 5 years but it has also clearly *slowed*. When one analyses what the report has to say about nutrition, one notices that the number of undernourished children under the age of five has dropped from 33% (in 1990) to 26% (in 2006). This figure of 26% corresponds to more than 140 million children (°UN, 2008). The 2010 Report stated that "*progress has also been slow in reducing child undernutrition. Close to one third of children in Southern Asia were underweight in 2010*".

Poverty also affects the education in developing countries. The United Nations report, which has been referred to before (°UN, 2008), shows that only 65% of children from the poorest strata of society in the countries surveyed had ever attended primary school (figures have been ameliorated as, according to the UN 2011, the enrolled percentage of children in poorest countries has grown to 76%). This percentage is opposed to 88% of children from the richest strata of the populations concerned (in 2010 the enrolled percentage of children in developed countries had remained stable at 97%). In addition, 84% of children in urban areas attended a primary school while only 74% attended such a school in rural areas. Even in refugee camps, only 6 out of 10 children are enrolled for primary education. In developed countries, as early as 2006, primary school enrolment rates for girls were equal to that of boys (100% for both genders) while in developing countries the rate was 94 girls every 100 boys who were enrolled (°UN, 2008). UN

2011 states that in the case of developing countries *"girls and boys have similar chances of completing primary education in all regions except for sub-Saharan Africa and Western Asia. In sub-Saharan Africa, boys are more likely than girls to complete primary education in 25 out of 43 countries with available data*".

While in developed countries the mortality rate for children under five years was 0.6% in 2006 and 0.7% in 2010, in developing countries it was 8% in 2006 and 6.3% in 2010 (°UN, 2008; °UN 2011). Of the 500 000 women who had died in 2005 (°UN, 2008) and 287 000 in 2010 (°UN, 2010) in childbirth or in the six weeks following delivery, 99% of these deaths in 2005 and 93.3% in 2010 occurred in developing countries. The number of women who died in 2005 from complications incurred during pregnancy in developed countries was 1 out of every 7 300 and 1 out of every 6 250 in 2010. The equivalent fatality rate in the sub-Saharan region (the developing region with the most fatalities during pregnancy and delivery), was 1 out of every 22 in 2005. The greatest concern for those who campaign for the treatment of HIV/AIDS patients is that the proportion of the population in developing countries who needed HIV retroviral therapy in 2007 was 31% while the equivalent figure was 22% in 2006 (°UN, 2008). In 2010 the situation is such that *"sub-Saharan Africa accounted for 70 per cent of new HIV infections in 2010, while it is home to just 12 per cent of the global population*" (°UN, 2010). Fifty two percent of people in developing countries living with HIV are not receiving antiretroviral therapy.

2.1.3 Learning in fundraising

The data and information provided by fundraising organisations, together with available reports and reviews of their activities, indicate that these organisations are becoming increasingly aware of the importance of motivating donors so that they will be willing to (at the very least) maintain the level of their past donations, even in the unfavourable economic climate that is currently afflicting the world. On the one hand, it is necessary that organisations focus on the public perception of the charitable or humanitarian work that they undertake as well as on their status as reliable and trustworthy organisations for only then they can continue to solicit funds from donors (Simon, 1995). °Chouinard (2011), introducing the fundraising guidance study undertaken by the Canada Revenue Agency, says that such a study is the result of "*growing demand from the public for more accountability from charities concerning their fundraising, as well as requests from the charitable sector for clarification of fundraising expense allocation for reporting and disbursement quota purposes*". On the other hand, it is vital to reinforce donors' perception that it is in fact their contributions which enable said recipient organisations to continue with their humanitarian activities. It is this perception (on the part of donors) that motivates them to continue making donations from one year to the next (Ajzen, 1991). Van den Berg et al. (2006) remark on the impact of both an affective and cognitive focus on the formation of attitude stating that "*the present findings demonstrate that an affective focus resulted in faster evaluative judgments*" and "*the faster evaluations in the affective focus seem to reflect a greater accessibility of evaluations than in the cognitive focus. This would support the notion that one of the determinants of the strength of an object-evaluation association in memory is the affective basis of the evaluation*".

The greater the number of donors which are made to feel that they are indeed playing a vital role in the maintenance of the organisation to which they contribute and in the realisation of its goals, the more likely they will be to continue supporting the organisation as long-term and stable donors. Abrams Research remarks how the internet should be used as an interactive tool where non-profit potential donors' awareness is engaged, nurtured and raised: "*New media forms provide unlimited platforms for data transmission, and are invaluable in the search for new donors or participants. Using a number of social media tools and strategies, nonprofit organizations can build an engaging online presence, and maintaining a blog and blogger outreach are two effective ways of reaching a larger subset of the targeted audience. As Internet trends rapidly shift toward social media outlets, a simple Internet presence is no longer an effective means of engaging an audience. Internet users expect websites to be "open": a frequently updated, interactive, direct connection to your organization*" (°AR, 2013). Research has indicated that if current donors are given informative, periodic information in a suitable format about the progress, achievements, hopes and intentions of the recipient organisations, they will be more likely to continue their support in the future (Ajzen, 2006). Fundraising organisations can maximise their donations by communicating impacts and using appropriate methods of solicitation if they implement those learning principles that have been proved to be effective in motivating people either to become donors or to continue making donations to those fundraising organisations that they have supported in the past (°NTEN, 2012; °Blackbaud (a), 2012).

Most fundraising organisations have well-established procedures for reinforcing favourable donor behaviour on the part of their benefactors or on the part of potential donors. The UNICEF working paper on Strategic Communication highlights that "e*vidently, addressing social and public health issues is not only about individual behaviour change but also about how the larger society manages and responds. It is about creating an enabling political and social environment for change in which the media plays a significant role. The quality of media reporting in turn shapes the public and policy discourse*". The paper further states that "*myriads of communication strategies have been used for almost a century to influence how people think, feel and behave. The private sector, which spearheads this process, relies heavily on evidence-based integrated marketing communication, which includes strategies such as advertising, direct marketing, personal selling, promotional events and public relation campaigns to name but a few. This approach to harnessing communication for selling products and services provides many lessons for promoting behaviour and social change in the social sector*" (°Unicef, 2005). These communication procedures vary according to whether donations are solicited via the Internet or as a result of personal, face-to-face solicitation activities. It has already been established that the potential for reinforcing favourable learning behaviour on the part of donors or potential donors is far more effective when the solicitation is made online. The reason for this is that information entered online can be processed far more quickly than information obtained from donors who are making donations personally in a face-to-face encounter. A Guide by °Convio (a) (2010) highlights the fact that fostering awareness in potential donors is a key aspect to planning an online media strategy. This should include "*a better understanding of the perception of your organization among supporters and detractors*" (°Convio (a), 2010).

2.1.4 The factor of human-interaction on the donation

Nowadays basically all main fundraising organisations (governmental and NGOs, for example the Red Cross [see °ARC, 2011; °BRC, 2012]; °UNHCR, 2013; Unicef [see °Unicef UK, 2012; °Unicef USF, 2012]; °Giving USA, 2012; UICC, 2013; Médecins Sans Frontières [°MSF (a), 2013; °MSF (b), 2013]) which operate online seek to reinforce favourable donor attitudes by providing them with carefully selected descriptions, figures and statistics to summarise the orginisation's achievements, future goals and needs. In some online donation cases, such as °Sightsavers (2013) and °Unicef USF (2013), graphics and animated interfaces are utilised to reinforce the benevolent intentions of current donors and motivate potential donors to become permanent benefactors of the organisation. Even when the quality of information is as sophisticated as this, the organisations concerned still do not benefit from the kind of immediate feedback on donor behaviour and preferences and various modes of interactivity that have been shown to be extremely effective in motivating current and potential donor behaviour. In most cases in which donation data is collected and meticulously processed before it is passed on to current and potential donors, no (or minimal) emphasis is placed on determining and responding to the personal preferences and wishes of donors. This often leads to system efficiency failure ascribed to donors' lack of awareness.

Huang et al. (2002) cite "*styling quality, message quality, meaningfulness, locatability* (easy to locate) *and metaphor"* as the five elements that are leading factors for GUI design. According to their study *"in addition to comprehensibility and identifiability, which previous results have found to be important icon design considerations",* meaningfulness and locatability of the above five factors are more important. In some cases the "newness" or "obsoleteness" of designed interfaces might play a huge role in keeping or dismissing online systems. A vivid example is VillageLife, a well-constructed graphic interactive online fundraising system, started in 2005 and eventually closed down in 2012 (°Wiki, 2012), the motivation being that "*web services technology has tremendously changed over the last five or six years. VillageLife was once new, now we focus on other models of online donation*" (°FELM, 2012). To this date, no similar or equivalent system has been made available to substitute it.

The proper utilisation of certain human factors is fundamental in effective face-to-face fundraising. Many fundraising organisations find it more effective to invest in the training of solicitors rather than to rely on the undoubtedly positive effects of proven online learning strategies. Both these methods produce far better results than traditional solicitation methods that rely on standardised brochures or people's commitment to future donations, usually by means of their signatures on a pledge. Surveys on F2F fundraising in times of recession and economic crisis (°Lake, 2008; °Jordan, 2009) show that face-to-face solicitation of donations is more effective than solicitation by means of online approaches. This phenomenon has been attributed to the value that donors place on human interactions, as well as on the greater availability of volunteers with better training into new soliciting approaches. °Lake (2008) reports that in fundraising F2F "*attrition is affected by key variables such as the type of charity, the level of the ask of the gift, the region of recruitment throughout the UK, and the brand awareness of the charity*". According to the °Blackbaud report, "*Donor Perspectives*" (2012), donors from the USA, UK and Australia which participated in a survey regarding the decision making process in relation to motivations, preferences and behaviours "*reported the top three factors that would impact their decision were: 1) An improvement in their personal financial situation; 2) Having passion about an organisation's mission; 3) Access to information that proved the impact of their contributions*". It is evident that the "human touch" is highly effective in keeping or augmenting the level of donation. Data and information provided to potential donors (in the form of pamphlets, brochures and other kinds of publicity material) should be readily available and up to date as "*tracking the impact of contributions and communicating that impact back to donors, not-for-profits can increase the number of regular donors and ensure they are not losing the regular donors they have*" (°Blackbaud (a), 2012).

It has been hypothesised that online systems might not necessarily become less effective if potential donors are computer illiterate or if they are unable to grasp the significance of the information received, but the absence of immediate human contact, interactivity and the warmth of face-to-face encounters diminishes the impact of the information that is offered by these soliciting organisations. The report "2012 State of the Nonprofit Industry" (Backbaud (b), 2012) highlights the contradiction which many non-profit organisations face: "*One thought provoking finding was that the popularity of donor recruitment methods did not always align with the perceived effectiveness of that method. For example, in many countries social networking was widely used, but very few organizations rated it as being an effective method. It may be that Internet-based donor recruitment methods are relatively low-cost, which means that nonprofits will use them even if they do not know the effectiveness. Perhaps organizations do not possess the tools to make the connection between social networking followers and donations*". Even though most fundraising organisations have long been aware of the fact that they have not yet maximised the potential of their donors (i.e. the amounts that individual donors would be willing to contribute under different circumstances), they have no idea how to attempt remedying the situation. There are a number of academic studies (such as those of Thorme & Root, 2002; Pritchett, 2002; Mondi et at., 2007) that demonstrate (1) how motivation is closely related to learning and (2) how goals that are relevant to the interests and concerns of learners, improve the quality of learning behaviour. Online giving still accounts for only a small fraction of nonprofit organisations' income (°Blackbaud (b), 2012).

In 2006, NetworkForGood (°NFG, 2006) released a White Paper which contained an analysis of peoples' "impulse to donate" in the case of natural disasters (hurricanes, tsunamis and earthquakes). The paper shows that people react promptly to catastrophes donating funds, goods and aid. However, as soon as media cover ceases, the donations rapidly *decrease* despite the fact that the situation is still dire and that the donors are aware of it. The peak donation period tends to last a few days (2-6 days) and after a rapid decrease, it asymptotically tends to return to fundraising standard conditions in a few months. The paper underlines that this phenomenon is related to "panic giving" and that the lack of efficiency of the fundraising organisation in dealing with the deluge, leads to the donors withdrawing their participation in response to the emergencies and the fundraising organisations consequently miss valuable opportunities to establish a continuous donation commitment.

Long and Chiagouris (2006) examined the factors that influence the credibility, and hence efficiency of NPO websites, by examining and analysing two major USA fundraising organisations (the American Cancer Society and the American Red Cross). Defining the *Attitude toward the Site* (AST) as a "*measure of an online user's predisposition to respond favorably or unfavorably to a website*" they come to the conclusion that "*if design related elements are major contributors to the credibility of website presence and eventual AST by visitors, then nonprofit managers already have methods and tools available to improve communications over the web with important constituencies*". Therefore "*the implication is that managers need to be even more sensitive about what interests people who visit their nonprofit website. Making sure that sufficient market research is conducted to find out what is on the minds of donors or volunteers or other important target audiences would be of value*".

Moon and Azizi (2013) highlight that "*internal traits (e.g., moral identity, altruism and volunteering orientation) are proven to influence individuals' donation decisions significantly*" and that NPOs' strategies (via promotion or solicitation) can influence such decisions. They also remark how "*from a behavioral perspective, understanding how fundraisers can persuade potential donors to give and how potential donors react to donation marketing are primary issues in relationship fundraising. Consumer behavior literature suggests interesting identity congruency strategies to persuade potential donors to give utilizing available demographic and psychographic characteristics, e.g., gender identity moral identity*". They also warn of possible negative reactions if targeted donors feel *manipulated.*

2.1.5 Existing technologies that promote fundraising goals

A well-known and established policy by many countries in order to support the fundraising efforts of non-profit organisations is to make direct contributions to their budgets or to create tax-related mechanisms for those who wish to donate funds to an organisation of their choice. The procedure one needs to follow in order to contribute to funds or gain tax reduction varies from country to country. In some countries, individuals and corporations are encouraged to indicate to their government their desire to support particular non-profit organisations. Their government then makes a pro rata donation from taxes to the organisations concerned. It has been a decades-long policy of many European countries to contribute to NGOs' financial activities by matching grant systems by which governments provide a contribution based on the organisations' domestic fundraising activities. These governmental participation quotas vary from 50 to 90% (Aldashev & Verdier, 2009; Smillie, 1995).

In recent years many governments (central as well as local) have started to retract their support to NPOs with still stronger cuts scheduled for the coming years (for example the UK, see °Hillier, 2012). This has probably inspired many NPOs to step up their communication with both existing and potential donors to help raise the missing funds. The National Council for Voluntary Organisations remarks in their 2012 Almanac, that "*civil society organisations are increasingly seeking to communicate directly with their beneficiaries and supporters through social media. While the size of their audience on social networks is not necessarily a good measure of success, it provides an interesting indication of their reach*".

Beside F2F and mail-based solicitation systems (the latter having proved expensive, ineffectual, cost-inefficient and not potential donor friendly), more and more fundraisers are making use of a variety of e-fundraising methods. Existing e-fundraising methods (according to °BlackBaud, 2009; °Kipnis, 2001; °Andresen & Mann, 2007) can be categorised in schemes that are:

1) Media-based
2) Internet-based
3) Sponsor-supported
4) Telephone-based

The 1) *Media-based* technology uses mainly radio and television programmes or inserts. While the fundraising organisations themselves usually pay the transmission cost of the programmes concerned, many radio and television channels offer a certain amount of free broadcasting time to approved organisations. The audio and audio-visual programmes and inserts (most of which are short commercials that appeal for donations to fund the activities of the group) are professionally conceptualised and produced so that they make the best possible impact on potential donors. These appeals for donations are called *aid solicitations* and they are inserted into specific types of programmes in order to achieve the greatest possible impact. In some countries government agencies offer various forms of assistance in order to assure an optimal distribution of these solicitations. According to Gruber et al. (2002) "*live fundraising events on television and radio are often expensive to stage. Often, a small fraction of the money received through donations ultimately go to the intended charity as so much money is consumed in the process of simply staging the live event. Furthermore, other means are often required to supplement the live events*". Occasionally, NPOs will utilise CDs or DVDs to get their message across to the public because these options are less expensive than inserting advertisements into scheduled programmes (°Convio (b), 2010).

The 2) *Internet-based* methods rely on the potentiality and versatility of the web. Allen et al. (2004) concisely state that "*your* [NPOs'] *web site can be a brochure, a news service, an information library, an activist center, a community meeting place, a store, and more, all in one. It allows you to present your mission and programs in their best light and interact in new and engaging ways with your constituents at their convenience. Your online communications can be delivered directly to people on their desktop computers or laptops, in the comfort of their homes or offices, 24 hours a day, seven days a week*". Soliciting donations tend to use the following three main methods of attracting voluntary workers and accumulating capital:

a) Appeal for online donations.
b) Offer online subscriptions that entitle respondents to membership of an organisation, a periodic newsletter and active support from the organisation for a specific length of time and by doing so creating a bond with the potential donors.
c) Appeal to committed individuals who will be prepared to donate specific, regular amounts.

While many Internet-based systems are frequently and, in essence, simply a kind of electronic carbon copy of what appears in the organisations' journals, they are also able to include far more data than contained in journals. Site maps help to avoid the "labyrinth perception" by cybernauts. The Internet-based format includes articles, fundraising figures, pictures and photographs, online videos, statistical graphical data that indicates the extent to which goals of the organisation have been achieved and links to other relevant websites. They also offer secure access to donation pages and the opportunity to leave messages and comments. In some cases, organisations offer small gifts in exchange for donations. Donors thus receive small but useful gadgets or other desirable objects as an expression of thanks for their generosity. This exchange of symbolic gifts for donations is effective because it increases the sense of relationship that donors have with the organisation to which they have contributed. According to Allen et al. (2004) premiums are great incentives for people to become donors and NPO subscribers. The analysis results of Ingenhoff and Koelling (2009), in their specific research of 134 Swiss NPOs, point out that the Internet's potential for interactive communication is still not being used efficiently by most of the examined organisations and this despite the fact that they seem to acknowledge its importance. Kang and Norton (2004) attained similar results in the USA in their analysis of the 100 largest NPOs: "*the selected NPOs were effectively using the Web to present traditional public relations materials and connect with publics. However, the organizations were* *largely unsuccessful in making interactive and relational communications with publics*". If, on the one side 85% of these NPOs provided mailing facilities, less than 10% had interactive communication systems (such as discussion forums [8.3%], chat rooms [4.2%], online polls [3.1%] and online surveys [2.1%]).

The 3) *Sponsor-supported* methods usually manifest in the following two forms (°NSF, 2003; °Moy & Morant, 2011; Andresen, 2011):

a) Hidden support methods. These methods are not necessarily hidden from view (although they can be at the discretion of the owner of the media or the sponsor of the provider). They are based on the calculation of a percentage of the commercial profits that devolve to the fundraising organisations involved. Usually corporations and foundations are among the main players.
b) Expressed support methods. In these cases, the commercial or legal entity aims at achieving a synergy between its own online products and the fundraising organisation concerned.

The use of 4) *Telephone-based* soliciting has recently been opposed by a number of consumer organisations and this method seems to be gradually falling out of favour. Telephone contact is nevertheless still used to make direct contact with potential and actual donors as well as gently reminding established donors that their donations might be overdue. Telephone surveys are also used to investigate specific problems and to gauge (by means of Gallup poll-type surveys) the kind of future support that an organisation might expect as they engage in strategic planning. °Harvey (2009), reported on a survey conducted by Intelligent Giving of 500 top fundraising organisations in the UK and telephone soliciting was the third-least cost efficient method for soliciting donations, ahead of the direct mail method and the use of newspaper advertisements. °Blackbaud's 2012 (b, 2012) survey shows that the use of mobile phone donations has become a strategy priority for many fundraising organisations.

The Internet has become a means of reaching out and communicating widely used by fundraising organisations in developed countries. Accordingly Ingenhoff and Koelling (2009) state that "*the differences between responsive and non-responsive charities in terms of usefulness of information for donor and media publics are striking...organizations which responded to the information request from donor publics generally provided Web sites with a higher information utility for donors (M= 64%) than organizations which did not respond (M= 55%)*". The quality of services and the methods used on websites do not vary much in proportion to the size of the soliciting organisation as much as in relation to their strategy policies.

While large and well-established fundraising organisations generally find it easier (partially due to the impact of their renowned programmes and organisation cost-efficiency) to use various forms of media technology, the smaller organisations tend to make effective use of local media and online programmes to generate support for causes. °Kipnis (2001) highlighted how NPOs failed donors by not *"interacting with them cost efficiently and effectively through a variety of media*" and "*customizing products or services based on individual preferences*". All NPOs tend to approach their potential donors in the same way. Their websites offer online opportunities for donors to contribute, to subscribe to membership of the organisation and to become volunteers. °Blackbaud (a, 2012) reports that results from their study conducted in the US, UK and Australia show that one of the main reasons for irregular contributions is the lack of feedback regarding the impact of the donor gifts. °Blackbaud summarises this interactivity problem and states that *"by tracking the impact of contributions and communicating that impact back to donors, nonprofits can increase the number of regular donors and ensure they are not losing the regular donors they have*".

2.1.6 To be or not to be: values for online learning paradigms

Throughout the world the commercial use of media has influenced the choice of approaches that NPOs make in order to achieve their goals. NPOs implement traditional and market acquired techniques in their strategies. This process is reflected in their websites which aim to attract the attention and cooperation of potential donors by combining statistical data with multimedia communication methods. Nevertheless, NPO managers and strategy planners frequently fail to take into consideration the donors':

a) *Saturation point*. The point of information overload at which a generic user has absorbed the maximum amount of data that can be handled at any given time without discomfort and that constitutes a top plateau of learning performance (°Daffron, 2013).
b) *Immunisation level*. In behavioural psychology, the condition in which users oppose a strong resistance to the messages contained in a media (see for example Murray et al., 1999).
c) *Cognitive dissonance*. The cognitive dissonance theory proposes that an individual reacts to an inconsistent mental condition by seeking means of removal of the discomfort and hence regain mental balance (Waters, 2009).

Discussion in both NPOs and sector research arenas has focused on the ways in which technological fundraising strategies could or should be changed for the better. On the one hand some feel a strong need to reach people individually (the *expansion strategies* of NPOs to explore and conquer new market sectors of potential donors) and to motivate them to enrol as donors whilst also encouraging established donors to keep up their support. On the other hand, some feel that advanced e-learning techniques are not adequately applied in order to improve the actual methods that are being used online as in F2F soliciting donations (*consolidation and improvement strategies*). Michael Lomotey (Business Manager at *Clothes Aid* since 2006) raises this second aspect of consideration and improvement strategies when he remarks that "*charities are well informed and very experienced when it comes to fundraising but there is a lack of research on the effectiveness of different methods of fundraising*" (°Harvey, 2009).

NPOs and fundraising organisations are aware of the availability of a variety of tools and methodologies to motivate and raise the awareness of both existing and potential donors. Often these same organisations tend to underestimate the communication possibilities inherent in certain modern forms of technology (Ingenhoff & Koelling, 2009; °Moy & Morant, 2011). One of the most important ethical imperatives for fundraising organisations is educating their donors and helping them to acquire a moral responsibility for giving and providing aid support as a necessity to the indigents. A criticism raised against fundraising organisations that have begun to operate as profit-making organisations that sell their products is that they have become oblivious to this educational aspect. In some cases, the drive to raise funds might have become the only dominant element and this state of affairs brings about disastrous results (°Stapylton-Smith, 2008). Great attention is devoted to planning strategies in order to accumulate the funds needed to maintain the organisation and its work and this is done at the expense of teaching donors about the importance and value of giving to charitable and humanitarian causes as a moral activity that is valuable in itself.

Online users who access fundraising organisation websites usually come across this following typical scenario:

1) The main page contains a number of links through which the user can access other categories of information.
2) An assemblage of pictures, figures, videos and diagrams explains *where* and *what* the most recent solicitation campaigns are addressing as well as *how* they have fared. This might be accompanied by extensive articles reporting on issues that would be interesting to possible donors.
3) Site maps are included which direct the concerned user to further explanatory information describing the history and mission of the organisation as well as information regarding past and present activities in which it has engaged.

4) Link(s) for accessing a secure donation page on which one, if you so desired, could record your personal data and commit yourself to making various kinds of donations as well as offer whatever other voluntary services the organisation may need to further its aims.

This kind of website structure and layout strongly resembles that of a well-organised (electronic) book which intends to provide its readers with the greatest amount of relevant information in the briefest, yet exhaustive, possible format. The title page thus serves to introduce the reader to what he or she might expect in the book. The links on the website are equivalent to content tables that describe and lead into the chapters. The articles on the site are equivalent to the chapters of the book. The site map serves the same function as the index whilst photographs, pictures and figures serve the same function in both formats. The secure donation page on the website is equivalent to a card inserted in the book, which solicits funds to cover production and distribution costs. Following this comparison, in the same way that unwieldy, unattractive and poorly organised books are unlikely to attract readers, so poorly organised, confusing and unattractive websites will attract only a few browsers and even less donors. A table of contents that contains incomprehensible and poorly constructed chapter and section headings will immediately alienate the average reader and in the same way, incorrectly indicated links will soon lead to confusion and a sense of navigating a labyrinth-like environment. Just as bland content fails to stimulate interest or motivate readers to continue reading the book, so a poorly written and presented website article inhibits browsers from further exploring said site. A reader who is intrigued by all the factors mentioned above will become more involved with the actual content and purpose of the book but a reader who is antagonised by all the negative factors referred to above will quickly lose interest in whatever the book has to offer – however valuable it may be. The previous parallels drawn between an effective book and a website that attracts and holds the attention of an online viewer, are helpful to understanding what precisely is required to make a fund-soliciting website effective.

Some organisations that (partly or wholly) use similar described informative graphic interfaces such as the Red Cross EU (°RCEU, 2013) and °Unicef CH (2014), are largely successful in educating donors as to the value of their contributions towards alleviating distress and furthering the work of humanitarian and charitable organisations. These websites still represent only a small fraction of those that should be designed in order to motivate new donors and persuade established donors to maintain their support. The vast majority of fundraising organisations tend to rely on the conscience and compassion of potential and established donors to motivate them to give or to continue giving, this regardless of the fact that handbooks on how to create website for NPOs (Allen et al., 2004; Harrison-Walker & Williamson, 2000) have long been in existence. In so doing, they place an inordinate emphasis on the kind of information that is contained in graphs, numbers and statistics – information that is mostly indecipherable and incomprehensible to the majority of non-specialist donors (Long & Chiagouris, 2006). This kind of approach is naïve and short-sighted and is bound to be ineffectual in the long term. Organisations that rely on such uninspiring, conventional and traditional methods of motivating donors will probably encounter great difficulty in increasing their budget and the number of their participant donors in the long run (Ajzen, 2006; Ingenhoff & Koelling, 2009).

Modern learning paradigms in the fundraising sector are strongly dependant on ICT which will completely transform the learning processes in the education industry within the next coming years (Hepp et al., 2014; Wastiau et al., 2013; Eng, 2005; Papert 1994; Papert, 1990). Thanks to the introduction of AI in computer embedded appliances and correlative interactivity, much progress has already been made in the transformation of education in highly developed countries. In the absence of catastrophic unforeseen circumstances, we can expect to witness a period of exponential growth in the use of e-learning as it replaces conventional "talking head" lecture-room teaching and learning in the education system (Glenn, 2008). Following a domino effect, similar transformation shall eventually occur in the world of fundraising technologies. It is vitally important to the survival of fundraising organisations that those who design their methods and approaches make full use of the proven successes of e-learning methods researched and developed in the academic world. If fundraisers incorporate the lessons pioneered by e-learning experts into their fundraising approaches, they will be able to not only educate and raise awareness in their donors, but will also be able to motivate established donors to consolidate their behaviours. Any NPO' failure to understand the way in which people have become accustomed to being approached in this electronic age is bound to undermine its own financial health and the administrative viability of organisations in the years to come.

The golden rule for the Third Sector, as formulated by Andreoni and Payne (2003), states that "*givers give primarily because they are asked. Stated differently, givers seem to have latent demands to donate. Until they are asked, this demand goes unexpressed...individuals who may have "always wanted to donate" but "didn't know the address" will be able to donate when solicited by the charity*". This rule will have to be adapted for a more sophisticated and intelligent milieu to match potential donors' expectations on donation strategies and goals and, as °Griffin

(2008) puts it, "*coming up with innovative ideas is vital for smaller charities*". Donation failure cannot only be simplistically explained in terms of limited resources due to economic crisis, as Breeze and Morgan (2009) state "*the evidence of existing research indicates no straightforward causal relationship between economic conditions and the amount of philanthropic spending that takes place. This is primarily because philanthropy is not a simple financial transaction, it is first and foremost a social act that enables people to pursue their passions, to support causes they believe in and to meet their own need to live a successful, significant and meaningful life which is affirmed by others*".

2.2 Research and Development in Robotics

Logsdon (2000) accurately depicts the difficulty of defining a robot by the telling of this anecdote in his book: "*A few years ago the members of the Robot Institute of America, a loosely organized federation of robot makers, held a special meeting for the purpose of developing a mutually acceptable definition of an industrial robot, but it turned out to be considerably harder than any of them would have expected. 'Everybody knows what a robot is,' quipped one member, 'but nobody seems to be able to define one.' For a while the Institute operated with a tongue-in-cheek definition: 'Any machine made by one of our members.' Later, they called another meeting and, after a long debate, finally settled upon a more useful definition: 'A reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices, through variable programmable motions, for the performance of a variety of tasks'*" (Logsdon, 2000).

The term *robot* is derived from Czech word *robota* meaning drudgery and tedious work. Even though the word was originally used to refer to automat human-like machines (Čapek, 2004) it is also often used to refer to any machine capable of autonomous movement. Wikipedia defines a robot as "*a mechanical or virtual agent, usually an electro-mechanical machine that is guided by a computer program or electronic circuitry. Robots can be autonomous or semi-autonomous*" (°Wiki (g), 2013). To avoid confusion concerning the type of robot, it has become customary to refer to human-like robots as androids (male resembling: *andr-* [male] plus *–eides* [alike]) and/or gynoids (female resembling: *gynē-* [feminine] plus *–eides* [alike]). The two terms are equally substitutable by *anthropomorphic* robot. The term *android* can be traced back to Albertus Magnus' (or Albert of Böllstadt, c1200-1280) allegedly referring to talking dolls as "androids" in Ephraim Chambers' Cyclopaedia (Stableford, 2006). However, the known oldest manuscript using this term is by Nauté (1653) which writes: "*Apres quoy si l'on veut insister avec Aristote que le bruit commun ne peut estre totalement faux, & que par consequent tant d'Autheurs n'auroient parlé de cette* ***Androide*** *d'Albert s'il* *n'en avoit esté quelque chose*". Despite common public beliefs the very first automated machines (i.e. robots) date back almost 23 centuries to Ctesibius of Alexandria (EB, 2013), a Greek physicist and inventor, who is reputed to have constructed a water clock clepsydra.

Research and development in robotics has already reached great hights due to the unlimited variety of possible applications and human inventiveness in creating new types of robots and variations. Any classification of robotics depends on the point of view and consequently what aspects are of interest and are meant to be highlighted in the robot. Classifications of robots can be made based on their mechanical structure, means of locomotion, sensorial identification, powering and deploying energy, dexterity, type of intelligence, interface, programme algorithm and so forth. A simplified classification of robotics can also be done based on: 1) industry related robotics (robots meant for production and commercialisation); 2) non-commercial robotics (mainly academic research and exploration robots) and 3) military robotics. From the perspective of this work, the robots can be further divided into *anthropomorphic* and *non-anthropomorphic* robots by defining some of their main usage characteristics.

Generally, research and development in robotics focuses on solving problems related to human *needs*. These needs can be *subjective* or *objective* in nature. The subjective needs directly relate to a person's struggle to achieve a personal performance, physical or psychical, and therefore requiring *subjective services*. The objective needs relate to a provision of services (*objective service*s), meant to provide extra non-personal tools to improve or take control of the management of the environment. Subjective and objective services can be interdependent. The imitation of human motoric skills, as in the case of research that focuses on solving smooth-motion movement issues related to specific joints (such as hands, hips, knees and pelvis) (Scarfogliero et al., 2004; Gravez et al., 2005; Martin et al., 2004) is aimed at subjective services. Environment recognition and analysis of visual data feedback for safe motion (as in Gini & Marchi, 2002), on the other hand, are aimed at objective services with subjective implications. The latter type of robot strongly depends on the acquisition of spatial dimension data (and sometimes also the temporal dimension for coordination), its analysis and interpretation and the processing of specific algorithms for the execution of specific (robotic) actions and reactions.

All robots designed to cooperate with humans are expected to possess the capability of communicating in human intuitive terms and, to this purpose, any interface should be user-friendly and designed to take into consideration the principle that there is a linear dependency between the robotic power and the need for humans to perceive own safety (Graf et al., 2002). Advanced sensorial implementations and control (autonomous or teleoperated) are a must for guaranteeing both human safety and acceptance of the robotics and therefore establishing any sort of efficient cooperation (Albu-Schaeffer et al., 2005; Alami et al., 2006). Actual state-of-the-art does not allow the validity of only Asimov's three laws of robotics since intelligence and autonomy in robots is far from being close to his envisioned scenario (Asimov, 1942) and human control over robots is a must for human security.

Hereafter is presented a state-of-the-art for anthropomorphic robots R&D in *industry*, *science* (and exploration) and *military*. An overview of *educative* and *advanced robots* is given, even though this does not directly link to humanoid robots but still adds to the understanding of technological developments and possible R&D spinoffs. These fields are interconnected and therefore easily overlap. Any exhaustive presentation on robotics, within the given limitations of trying to frame a continuous dynamic research and development scenario, would require a book-level work which is not the goal of this subchapter and therefore data limitations are enforced.

The robot cases presented in subchapter 2.2 were identified through conducting word searches with internet search engines, looking for the most cited and referenced cases and articles. The words most used in the search were combinations of (in alphabetic order): android, anthropomorphic, assistive, development, educative, gynoid, HRI, human, humanoid, industrial, intelligent, interactive, interaction, interface, machine, manipulator, military, research, robot, robotics and toy. In addition, links found in the references of the identified articles, were searched to further explore the most pertinent articles.

Even though robots for household service make up a surging sector of prospective pervasive robotics (robotic mops, vacuum cleaners and lawn movers are among the best known) with an annual growth of 20% (Manyika et al., 2013), this category, after having been compared to what other sectors had to offer, has not been included in this presentation.

2.2.1 Anthropomorphic Robots

Most of the R&D studies in the field of anthropomorphic robots aim at more or less producing a mimicking of human behaviours or the reproduction of some of the fundamental exterior characteristics of humans (facial expressions, appearances, speech abilities, comprehension and dexterity etcetera). The industry stepped into the development of technically advanced anthropomorphic robots with a concrete breakthrough in the creation of Honda's °ASIMO (2000) which was soon followed by more human resembling robots with special behavioural features. Advanced robots, with the capability of providing partial intelligent response to interlocutors' actions or speech (Kondo et al., 2013), have been developed. Combined studies are being conducted on robot expressiveness and human-robot interaction (HRI), as in the case of the Geminoid HI-1 and Geminoid F (Becker-Asano et al., 2010; Becker-Asano & Ishiguro, 2011). The embodiment of the robots is affected by various factors and, in particular, the local environment, the needed/expected dress/appearance and the contingent situation all play a role in dictating the successful integration of the robot in the human interactive environment. The quality of the motions and reactions to human activity allow the robots to be perceived as *almost human*. Hence the actuators, sensors, the intelligence and DOF (Degree Of Freedom) (Norton, 2003) all combine to influence the level of acceptability of the robot as a humanoid artefact. MacDorman et al. (2013) state that "*anthropomorphism tends to increase with human realism; people are more likely to ascribe human qualities to objects that look and act human—and to evaluate them positively*". Ishiguro, a professor at Osaka University (and one of the designers of Geminoid F and its predecessor Repliee Q1Expo), in reference to the gynoid said "*I soon realised the importance of its appearance. A human-like appearance gives a robot a strong feeling of presence...we have found that people forget she is an android while interacting with her. Consciously, it is easy to see that she is an android, but unconsciously, we react to the android as if she were a woman*" (°Whitehouse, 2005).

Anthropomorphic robots are characterised in terms of *presence*, *embodiment* and *identity*:

a) *Presence* refers to the robot's intended physical existence that augments its salience (Kiesler et al., 2008). People must perceive the robot as an individual and physical entity. The robot needs to function as part of the environment and thus it uses sensors to perceive its surroundings and models to identify, via an intelligent system, the surrounding objects, distinguishing between fixed and mobile objects. One class of robots that requires a sense of their presence more than others is *mobile robots* as they need to identify obstacles and other mobile beings or objects in the course of moving themselves. Schultz et al. state that *"mobile robots are now in a state where they can safely be deployed in populated environments. In this situation, the ability to know where persons are and where they are going to becomes increasingly important. Knowledge about the trajectories of persons can be used to improve the navigation behavior and the interaction capabilities*" (Schulz et al., 2003).

b) The *embodiment* of a robot is the personification of intellectual, cultural, emotional and even cognitive elements which are purposefully included by the designers or developed by the robot and perceived by humans which interact with it. As in the case of humans and virtual humans, the embodiment of a robot can be characterised in terms of appearance and body language as well as observational and navigational skills. The robot needs to express, in its being, the quality and functionality it was originally designed for (Feil-Seifer & Matarić, 2009). The robot expresses communication skills in HRI in terms of aural or visual means and is capable of initiating a conversation of sorts. The programmed behaviour of the robot must convey the concept of its intended purpose and therefore it will move and talk according to such purposes or scopes. Mobile robots require skills not only to define their environment, but also in choosing and calculating a correct pattern to reach a specific destination. They can thus transform all input data, via sophisticated algorithms, that allows for the recognition of defined models (Kiesler et al., 2008). Generally anthropomorphic robots must, to a certain degree, be capable of mimicking body language (i.e. via gestures and mimics). However, in certain circumstances it can happen that people attach more value to the robots than the intelligence of said robots would deserve (Fink, 2012). A parallel field of R&D to anthropomorphic robots is biorobots: a class of robots that embed characteristics of appearance and body language and that can simulate behaviours of living beings (Webb & Consi, 2001).

c) The *Identity* of a robot renders it capable of carrying a personalised character, with specific distinguishable behaviour, which makes it recognisable in a community of humans and other robots. This is made possible by a profiling feature that can be dependent on users' history or the robot's experiences (see for example Iida & Hara, 1999; Lee et al., 2006). Such profiles (packs of memory) are stored as metadata in the database of the robot, awaiting activation and decryption to create, via the use of given algorithms, new behaviours. The identity is primarily expressed through communication and in some cases via created artefacts, such as records of interactions with users (Leon et al., 2013; Iida et al., 1998).

A short collection of some of the most advanced anthropomorphic robots is given in Table 1. The selection of the robots on this list was made based on the fact that the humanoid robots are constructed according to the newest or latest known design criteria. These robots have been designed by a reliable source (renowned enterprises, organisation or research institutes) and are amongst the most cited by technical or academic papers. These robots were selected for their skills and special advancement in their sectors of locomotion, human expressiveness, force or sensibility in carrying out their tasks, human mimicking and so on. There are many anthropomorphic robots which are not included in Table 1 because of their strong limitations due to being too generic (for example low-price commercial robots with reduced capacities) or too specific research-oriented (i.e. neglecting the overall humanoid robotic development). Table 1 consists of four columns and gives a schematic overview of:

1) The organisation and/or author responsible for the robot's construction or design. The name(s) of the robot(s) is supplied in parenthesis.
2) The leading research questions posed by the author (or designer).
3) The known obtained answers/results with the development of the robot. Robots are defined as autonomous when acting independently without a live human supervision or teleoperated when humans are in control, via telecommunication means, of the robot's features.
4) The unanswered questions (or open issues).

Pictures of the presented robots are supplied in Table 2.

Table 1: Anthropomorphic Robots at a Glance

1) Author	2) Research Questions	3) Achieved Results	4) Open issues
Honda Industries (P2, ASIMO) °ASIMO, 2000 Behnke, 2008 °Kaur, 2012 °CSR, 2012	1) To replicate the complexities of human motions. 2) To walk around in surroundings that include mobile objects.	The ASIMO robot can imitate most human movements (i.e. walk, open doors etc.) and recognise vocal tracks. Can recognise and locate speakers. Autonomous robot	Practical applications and use of the robot and its concrete aiding skills. Common users' reaction and interaction behaviours concerning the robot. People's acceptance of the robot's partnership.
Toyota Motor Corporation (HSR - Human Support Robot) °Falconer, 2012 °TMC, 2012 °Ackerman, 2012	1) Efficiently assists humans who experience mobility problems. 2) Dexterity in robotics.	Picks up and carries small light weighted objects. (This is part of *The Toyota Partner Robots* which can play trumpet, tuba or horn by *blowing* with its own lips.) Teleoperated robot	Precision and capacity to select from an array of objects. Human emotional reaction and interaction in response to the robot's presence and performances.
Kokoro Company Ltd Ishiguro et al. (Actroid , Repliee Q2, Geminoids)	1) Verbal communication and eye contact. 2) Interlocutor position recognition	Face and torso muscular mimicking. Understanding of more or less 40 000 phrases and capability	The specific role(s) of the robot in the communication and its scopes in the learning processes of

Ogawa et al., 2012 Heracleous et al., 2011 °Hollister, 2011 Nishio et al., 2007 °Dybwad, 2005 MacDorman et al., 2004	and generation of motion patterns. 3) HRI and Robotic camouflage.	of answering with 2 000 sentences in 4 languages. Partial acceptance of robot presence. Teleoperated robot	the users.
KAIST Oh et al. (HUBO2+, HUBO Golem) O'Flaherty et al.(a) 2013 O'Flaherty et al. (b)2013 Grey et al., 2013 °Rich, 2012	1) Kinematics and limb control. 2) Dexterity.	Walking and basic handling of objects. Finger mobility and grip capacity. Teleoperated robot	Absence of HRI evaluations.
PAL Robotics (REEM [-C, -H2]) Marchionni et al., 2013 Agravante et al., 2013 °Fairhead, 2013	1) Human assistance. 2) Verbal communication. 3) Dexterity.	Moving around on wheel base [-H2]. Walking [-C]. Basic handling of objects. Speech recognition and interaction. People tracking. Autonomous robot	Assessment on HRI is not available. The more autonomous known robot version –H2 does not have legs.
NASA, General Motors, OSS Diftler et al. (Robonaut 2) Barajas et al., 2013 Diftler et al., 2011 °Guizzo, 2011	1) Dexterity. 2) Sensing and control of force. 3) Human partner in space works.	Robotic dexterity and self-management. Teleoperated robot	HRI assessment is missing. The robot does not walk.
Aldebaran Robotics (Nao) Lopez Recio et al., 2013 Mubin et al., 2013 Csapo et al., 2012 °NAO, 2012 Papangelis, 2012 Tanaka & Matsuzoe, 2012 Meena et al., 2012 Sousa et al., 2011	1) To replicate human motions. 2) Verbal communication. 3) Reprogrammable abilities.	Moving around. Walking, dancing. Basic handling of objects. Speech recognition. People tracking. Autonomous robot (can be teleoperated)	Precision and power in handling objects. Locomotion limitations. Fragmentary assessments regarding human emotional and cognitive interactions with the robot(s).
AIST Yokoi et al. (HRP-3L [4 - 4C *gynoid*]) Miura et al., 2013 Kaneko et al., 2011 Nakaoka et al., 2010 Nakaoka et al., 2009 Kaneko et al., 2008	1) To replicate human motions. 2) To imitate facial expressions.	Moving around. Walking, dancing. Objects tracking. Autonomous robot	HRI assessments. Locomotion on non-level ground.
Boston Dynamics DARPA	1) To substitute humans in dangerous	Human safety. Fast moving across	HRI assessments. Safety in cooperating

(ATLAS) °Markoff, 2013 °Hornyak, 2013 °Kolawole, 2013	environments. 2) To test human protection suits.	non-level ground. Handling of objects. Operating mechanisms. Objects tracking. Teleoperated robot	with humans.

Apart from a few cases listed (including some in which proper analytic data is missing or unavailable) it is noteworthy that a proper HRI description and a methodological emotional-cognitive human behaviour assessment is absent.

The pictures in Table 2 below show how the robots, referred to in Table 1, look. Dimensions vary from that of a little child (as in the case of NAO, a mere 53 cm in length) to a fully grown adult (the HRP-4C gynoid is 158 cm tall while Atlas is 188 cm).

Table 2: Images of Designed Anthropomorphic Robots

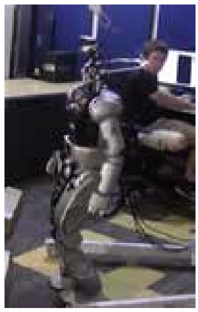
 **Figure 3:** Geminoids (*003)	 **Figure 4:** HUBO+ (*004)
 **Figure 5:** REEM-C1 & REEM (H2) (*005)	 **Figure 6:** Robonaut 2 (*006)

Figure 7: NAO (*007)

Figure 8: Asimo (*008)

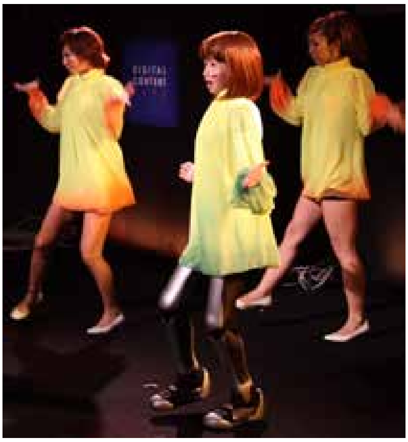


Figure 9: HRP-4C (*009)

Figure 10: Atlas (*010)

Figure 11: HRS (*011)

Figure 12: HAL (*012)

Table 2 also includes HAL (Hybrid Assistive Limbs), a work assisting robot suite which is a relatively slim exoskeleton meant to support human limb motions. Its intelligence and mechanics can boost and support the natural movements of limbs by providing extra power while its sensors can monitor the user's health. HAL is the first human size exoskeleton and it kindles strong hopes for efficient future R&D in human-robot biomechanical and biomedical integrations (Fleischer, 2007; Sankai, 2011; °Kawamoto et al., 2013).

Considering the high ideals with which some robot designers approach the areas of robotic intelligence, dexterity and efficiency, the °RoboCup (2013) organisers probably encapsulate it best when they state that *"by mid-21st century, a team of fully autonomous humanoid robot soccer players shall win the soccer game, comply with the official rule of the FIFA, against the winner of the most recent World Cup*".

2.2.2 Industrial robots

Manipulator robots, programmable robots capable of moving and handling objects with high precision, were first introduced in 1954 by George Devol. He referred to these types of robots as Universal Automation or Unimation and when introducing them, he highlighted both their technical benefits and alluded to future developments stating: *"The present invention makes available for the first time a more or less general purpose machine that has universal application to a vast diversity of applications where cyclic control is to be desired; and in this aspect, the invention accomplishes many important results. It eliminates the high cost of specially designed cam controlled machines; it makes an automatically operating machine available where previously it may not have been economical to make such a machine with cam-controlled, specially designed parts; it makes possible the volume manufacture of universal automatic machines that are readily adaptable to a wide range of diversified applications; it makes possible the quick change-over of a machine adapted to any particular assignment so that it will perform new assignments, as required from time to time*" (Devol, 1961).

Robots are used in industry for almost any kind of work, but in particular those areas which require repetition and precision without loss of continuity. In this regard Wallén (2008) states that "*in general, industrial robots are used to reduce costs, increase productivity, improve product quality and eliminate harmful tasks. These areas represent the main factors resulting in the spread of robotics technology in a wider and wider range of applications in manufacturing industry*". The fact that robots are potentially great substitutes for humans who do heavy-load labour, navigate in bio-chemical or radiation hazardous environments, puts them at the top of the R&D priority list for the exploitation of technology. Assembling, soldering, painting, packing, quality checking, heavy-load transportation, surveillance, danger detection and processing are among the most relevant qualities for which industrial robots are known and in demand. Research in the sensorial and data interpretation sector has allowed for the combination of visual capturing techniques with intelligent algorithms (see Cielniak & Duckett, 2003; Frese et al., 2005). This development has opened up opportunities to robotic upgrades as sensors have become a must medium to support robotic intelligence in perceiving their environments and coping with their tasks. Chen (2013) says that *"for human, eighty percent of all information in the brain comes from the eyes. The visual system in a robot can greatly affect its intelligence. The intelligent merit of visual systems challenges both academic researchers and practical engineers to timely provide analytics theory and systems solutions to meet the high-performance need of robots. The challenge may exist in either hardware or software*".

When one considers their *autonomy* industrial robots, for reasons of simplification and easy identification, can be divided into two main classes:

1) *Repetitive robots* that carry out pre-programmed functions. These types of robots are usually less demanding in terms of sensorial and programming characteristics.
2) *Scope-adapting robots* use a degree of flexibility to carry out their intended functions. This kind of robot strongly depends on AI (Artificial Intelligence), multi-sensorial analysis and self-recalibration skills.

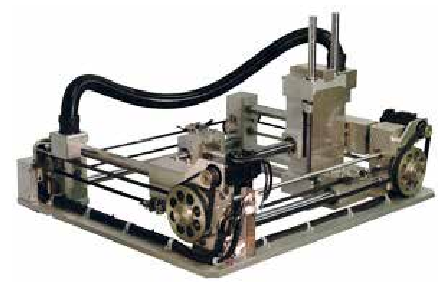
In addition to *autonomy*, industrial robots can be also be classified according to *how* their movable components move in relation to their axis (sliding or rotating):

1) *Cartesian coordinate robots* (or *gantry robots* or *linear robots*) have their three controls sliding on their axis that are set at right angles. They are simpler and easier to manage but present limitations in special Work Envelopes (i.e. the workspace volume reachable by the robot effectors) (Altintas, 2010).
2) *SCARA (Selective Compliance Assembly [Articulated] Robot Arm) robots* have three DOF of rotation on the plane xy (one is taken by the effector) and one in the linear sliding on axis z of the terminal link that holds the effector (Amiri et al., 2009). SCARA robots are considered a type of articulated robot.
3) *Articulated robots* have rotary flexible joints that allow for the mobility of neighbouring links. Joints are provided with sensors which define rotations and speed. This class of robot has developed many various advanced forms thanks to the possibility of chaining the joints or sequences of links and joints (Inczedy et al., 1998; Goto, 2010).
4) *Parallel Delta robots* (or simply *Delta robots*) have three parallelograms (acting as three axes) that rotate on levers and two platforms at their

extremities. The fixed higher platform carries the motors and the mobile lower one carries the effector. A fourth element can be present between the two platforms to transmit a rotation (fourth axis). These robots are designed for high-speed manipulation and/or the pick and place of usually small dimensional objects (°Bonev, 2001; Poppeová et al., 2011).

Table 3 below provides some examples of industrial robots with a short informative summary and an indication as to which "category" they belong to. The scope-adapting robots are the best candidates for becoming human co-workers under the premises that stable security and operative intelligence are guaranteed. Recent developments in the field of industrial robots have moved into the domain of anthropomorphisation to create acceptable HRI. This is also the case with the Baxter robot which is discussed separately in this section.

Table 3: Examples of Industrial Robots

 **Figure 13**: Sacmi Pakim Dynamic-Palletizer by Layer [Cartesian coordinate robot] (*013). Palletizer with single or double layer.	 **Figure 14**: Janome JSG gantry series [Cartesian coordinate robot] (*014). Flexible overhead positioning servo robot.
 **Figure 15**: Stäubli TS80 [SCARA robot] (*015). Four axes robot.	 **Figure 16**: EPSON RS3 [SCARA robot] (*016). Zero footprint robot (i.e. no dead space of work hence full Work Envelope).

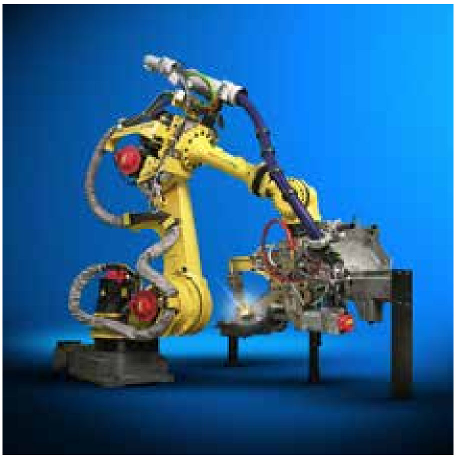


Figure 17: Fanuc M-20*i*A [Articulated robot] (*017). Welding robot with vision and self-inspection.

Figure 18: KUKA KR 60 [Articulated robot] (*018). Foundry robot.

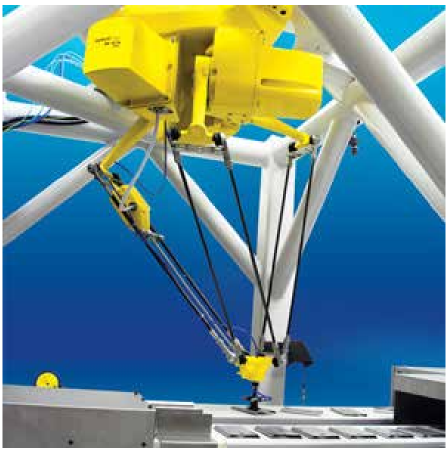


Figure 19: FANUC M-2iA [Delta robot] (*019). High speed picking and assembling robot.

Figure 20: ISIS SurgiScope [Delta robot] (*020). Robotised tool-holder for microscope-assisted neurosurgical procedures.

Developers and researchers in the area of industrial robotics tend to eliminate the robotic work environment barriers (*fences* or *cages*) which have traditionally accompanied robotic implementations for human safety reasons. °Anandan (2013) succinctly summarises the actual situation regarding the development of advanced robots in industry: "*Our contemporary coworkers have one thing in common. They can operate in the human-occupied workspace without safety fencing. This species of robot is cage-free. That doesn't mean their workspaces are devoid of safety peripherals, but gone are the elaborate safety guarding systems of their heavyweight cousins. The fences are coming down. Robots are being seen in a* *whole new light*". This new form of work cooperation should take into account Fong et al. (2002) findings which relate to the creation of collaborative control systems since "*when humans and robots interact to achieve common goals, they are subject to team related issues. In particular, teamwork requires team members to coordinate and synchronize their activities, to exchange information and communicate effectively, and to minimize the potential for interference between themselves*".

The Baxter robot (*scope adapting* and *articulated* robot) is an anthropomorphizied industrial robot capable of expressions via its touch screen monitor. The two eyes on the robotic screen show its actual focus point, situational expressions and even concerns in the case of unneeded human proximity. The Baxter robot (Figure 21) is apt to *learn* its own duties and tasks from a human co-worker (Bogue, 2013). Manyika et al. (2013) note that "*when the robot is first installed or needs a new routine, it "learns" without the need for programming. A human simply guides the robot arms through the motions that will be needed for the task, which Baxter memorizes. It even nods its "head" to indicate that it has understood its new instructions*". The robot has proximity sensors for human safety analysis and is aware of the surrounding environment (°RB, 2013). The robot's arms are capable of adjusting their fluid movements and can calibrate their precision and power according to the sensed external forces (°Titlow, 2013).

Figure 21: Baxter robot (*021)

2.2.3 Military and security robots

Some of the most promising R&D in the sector of robotics is funded by military or security related organisations. Although this research rarely focuses on anthropomorphic robots (an exception is the Atlas robot included in Table 1) some of the outcomes are highly valued for their additions to limb and sensorial efficiency as well as locomotion stability. This subsection presents the most relevant cases. Due to the intended purposes for these robots and their final utilisation, scientific data concerning the design of this category of robots is quite scarce. Corroborated data is used here to show some of the advancements in this sector of R&D. Pictures of the robots discussed are enclosed in Table 4.

1) The Legged Squad Support System (LS3) is a robot created by DARPA (Defense Advanced Research Projects Agency). It is a mule-type robot (also referred to as Big-Dog) which is capable of moving over uneven terrain and navigating difficult weather conditions (°AT, 2012; °Ackerman (a), 2013; Raibert et al., 2008). It is capable of analysing its surroundings in full day light as well as in very low light (near infrared vision) which enables it to choose and regulate its own pace while carrying heavy loads. It recognises its partners and can receive vocal orders. In case it slips, it is capable of raising itself back onto its feet. It is partly bulletproof (even though it is not expected to work in combat areas). Its intelligence and robustness set a milestone for robotic integration of dexterity, power and intelligence (Ma et al., 2012; Bajracharya et al., 2012).
2) Up until now, the tethered robot Cheetah (°Lewis et al., 2011) is the world's fastest quadruped robot reaching speeds of up to 45.5km/h (Spröwitz et al., 2013). Cheetah is the result of a project focussing on robotic high speed and locomotion stability. Its galloping action has been tested on a treadmill whilst the robot itself is not autonomous. To support its speed the robot has been designed with the capacity to arch its back (using a Differential Actuated Spine) (°Falconer, 2013) which increases its stride and motion fluidity. This feature strongly recalls the movement of the cheetah. This robot, together with the LS3, is the precursor of the autonomous WildCat robot (°Wall, 2013) which can perform at high speed with stability while retaining autonomy (°Vincent, 2013).
3) The autonomous robot Care-O-Bot 3 (Amirabdollahian et al., 2013) is a mobile robot designed for service and surveillance capable of recognising people and surroundings while keeping track of human behaviours. The robot has a 7 DOF flexible arm which is capable of adjusting its grip force as well as a screen interface used for communication (human-robot or human-operator-human). The robot can be teleoperated or directly guided by vocal commands issued by a present human. The robot, in its dual function, is capable of partially assisting humans (tests are being conducted in European hospitals as well as care facilities for the elderly) through the use of its manipulator limb. It can also act as a security surveillance guard with some interacting intervention skills whilst at the same time communicating with a remote supervising human who can alert it to specific problems (Graf

et al., 2009; Reiser et al., 2013). Kristoffersson et al. (2013) give an overview of the existing teleoperated mobile robots with a description of their applications. All indication is that this sector is rapidly growing.

4) The surveillance robot Robo-Guard (°Scott, 2013) was designed to patrol prisons. It is an autonomous robot but can also be teleoperated. The robot is capable of interpreting human behaviours and can decide how to react on its own it. It can communicate with prisoners via loudspeakers and transmit an awareness of risks and dangers to human guard supervisors who can, in turn, use the two-way communication system to talk to prisoners from a remote location. The robot possesses multiple cameras (of which one is 3D), a microphone and a software system that allows it to patrol designated areas (°Yirka, 2012).

R&D in the security and military sectors tends to focus on robots that complement or substitute some part of human activity whilst maintaining concerns for the safety of both robot and human partner in the execution of the task. The design of these robots strive for intelligent autonomous locomotion and, whenever feasible, teleoperated control. AI and sensorial integration are fundamental for the efficiencies of robots in this class. Robots meant for outdoor activities must exercise locomotion adaptability for uneven terrains, structure robustness, efficiency in terms of quality and speed to carry out their tasks and payload power. Indoor robots are not usually expected to have high locomotion skills (i.e. the navigation software is simpler) but their structure tends to be more robust (i.e. the robots usually have a protective shell).

Table 4: Examples of Military and Security Robots

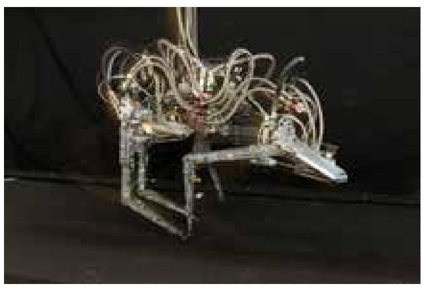
 **Figure 22**: LS3 Legged Squad Support System DARPA – Boston Dynamics (*022)	 **Figure 23**: Cheetah DARPA – Boston Dynamics (*023)

	
Figure 24: Care-O-Bot 3 (*024)	**Figure 25**: Robo-Guard (*025)

2.2.4 Companion and Educative Robots

Arkin et al. (2003) point out one of the key elements necessary in designing successful toy robots stating that "*human-robot interaction is of critical importance in the entertainment robotics sector. In order to produce a desirable end product that can be enjoyed over extended periods of time, it is essential that an understanding of not only robotics but also human psychology be brought to bear*". In recent years, interdisciplinary human perception in HRI and its outcomes have become more of a focus and this has been used at various levels in the robotic sector. Fink (2012) comments "w*hat brings together anthropomorphic design and social robotics is the fact, that the appearance and function of a product impacts how people perceive it, interact with it, and build long-term relationships with it*". Groom et al. (2009) add to the issue of interaction by remarking how "*the degree of anthropomorphism in robotic form affects how people interact with robots. Experimental research has demonstrated that more anthropomorphic robots are praised more and punished less in collaborative human-robot team interactions...In some cases, matching anthropomorphism to the robot's task, making more social robots more humanlike in appearance, can improve the interaction*".

This subsection, regarding companion and educative robotic R&D, shows how the need for effectiveness of the entertainment sector has striven to jump ahead into friendly acceptable robots and by what means. Once again, information relating to human psychological behavioural elements and how this has been taken into account in the robots' design schemes, is scarce.

The presented robots were chosen from among many and are referred to in literature as sectorial leading robots for their specific characteristics. The list does not intend to be comprehensive, but representative of some features that serve as a reference platform. Pictures of the robots can be found in Table 5.

Pleo is an entertainment pet robot (or companion robot) intended for special psychological induced interactions (°Engler, 2013). The robot looks like a newly born Camarasaurus (a vegetarian Dinosaur) and possesses cameras, microphones and vocalisation abilities. It has been tested by a crew during a simulated trip to Mars to verify its level of efficiency in the reduction of stress and providing psychological relief to each participant in the simulation. Its behavioural programming, in passive or active modality, allows different HRI stimulations and reactions. The passive interaction mostly accommodates human initiatives in the HRI, while the robot encourages human actions by emotionally praising them. The active interaction gives the robot the option to stimulate and attract human attention through its behaviour. The robot is capable of learning from HRI and can adjust its attitudes accordingly. Besides this, it is also capable of exploring its environment and can retain a partial memory of it. No in-depth analysis is yet available for the cognitive and psychological evaluation of the Pleo HRI. Nevertheless, it has been observed that to facilitate Pleo's long term effects in the HRI, the interaction should initially be forced on users and only later a somewhat natural relationship can be observed (Jacobsson & Nylander, 2012).

Paro is a baby seal robot designed to assist with pet therapy in geriatric care centres (Wada et al., 2008). The robot has been designed and tested to work with people who suffer from Alzheimer's disorder, dementia, depression and apathy. According to Moyle et al. (2013) it is reported that that the interaction with the robot has positive effects on ill people and that it generally adds to their quality of life (relaxation, motivation and improved interpersonal communication). Paro has sensors for tactile inputs and reacts to touch (i.e. the robot responds with sounds and movements when being touched in specific areas). The robot reacts to sound and turns its head and eyes in the direction of the person who is interacting with it. Its engines allow it to blink and move its tail and it can learn users' most frequently used words and react to them. Its intelligence allows it to modify its behaviour according to changes in people's attitude and adjust to stimulate their actions. The robot uses its sensors to keep track of temperature, light and sound and adapts its behaviour accordingly, following a diurnal rhythm. The emotional expressivity of the robot promotes interactivity. The examination and analysis of some test data suggest that, in future, one could focus on user centric and environmental data observations (Moyle et al., 2013).

iCat (produced by Philips) is a robot that is used in HRI studies. Many research institutes have been using it to examine and assess human behaviour in HRI (Midden & Ham, 2009; Hindriks et al., 2012). The robot can express facial emotions according to the given interaction and environmental situation (°PRT, 2013). The motors in its head allows the robot to turn towards interlocutors. Microphones, loudspeakers, camera, led lights (which adjust their colours according to the robot's modality) and touch sensors are also embedded in the robot. The sensors afford the robot a perception of the situation. The robot is capable of speech recognition and, in turn, it can talk and respond (verbally and with facial expressions) to users. Its intelligence allows a high level of interaction. In addition, the robot can be teleoperated for more advanced test cases following the Wizard-of-Oz schema (Hindriks et al., 2012).

PaPeRo (Partner-type-Personal-Robot) *mini* (°DZ, 2013; °Owano, 2013) is an interactive robot toy capable of scanning its surrounding environment and adapting to it. The new *mini* robot, based on and a successor to the PaPeRo larger version, has a camera (for visual detection), microphone, sound sensors (ultrasound), touch sensors, thermometers, colour light system and loudspeakers. It is capable of speech and face recognition as well as speech synthesis (Sato et al., 2009). Seemingly, the robot is upgradeable with new sensors and defined behaviours make it one of ICT's most flexible robots. The robot can detect the presence of humans and initiate a conversation. Even though the robot is quite versatile in many functions (Sharkey & Sharkey, 2010, Han, 2012) there is a scarcity of data as regards its HRI analysis and the corresponding human interactive behaviour. The robot has been used in companion therapy for elderly people suffering from dementia but specific feedback data is lacking.

Kaspar (Kinesics and Synchronization in Personal Assistant Robotics) is an interactive robot used by research institutes for HRI analysis, particularly in relation to children's assistive play and ASD (Autistic Spectrum Disorder) therapy (Dautenhahn et al., 2009; Wainer et al., 2010; °Joss, 2013). The facial expressivity is generally limited; visual (cameras are situated in the eyes) and aural sensors (a microphone for sound detection) combined to motion sensors located in the limbs allow for some sort of dynamism but with low speed and precision of movements. Nevertheless, the programmed and adapted robot (it can be built with off-the-shelf components) is effective in inducing positive HRI with normal children as well as children diagnosed with ASD (Wood et al., 2013; Dautenhahn et al., 2009).

Nexi, a Mobile Dexterous Social (MDS) robot, is a wheeled robot with a meagre outfit but with ample facial expressions and locomotion skills (Bradley Knox et al., 2013). The robot is intelligent and is integrated by its hands, which are capable of manipulating objects, its eyes (cameras) plus a 3D infrared camera that allows for visual detection of the surrounding environment and microphones (located in the ears) that allow for the detection of humans or sound generating objects. The robot is used for academic research and HRI studies (Jung et al., 2013, Lee & Breazeal, 2010). The main purpose of this type of robot is that the analysis of feedback generated by test cases as well as the collection of various observations allow for further development of acceptable robots in HRI (°Fingas, 2012).

iCub is a humanoid robot meant to study and assess HRI behaviours (Natale et al., 2013), functional development strategies (Lallee et al., 2010) and even robotic cognitive behaviours (Mohan et al., 2011). The robot has a high level of dexterity (it possesses 54 DOF) and is capable of interacting not only with humans but also with its surrounding environment. iCub has cameras (vision), microphones (speech synthesis and voice recognition), tactile sensors (to quantify its force usage, torque, pressure and grip conditions) and proprioceptors (to allow for locomotion). The robot is capable of locomotion and can learn from self-analysis and own situated conditions (i.e. recognising its own physical elements or learning from its own interactions). This robotic approach constitutes a move towards gifting the robot with self-consciousness via learning behaviours (Nguyen et al., 2013; Natale et al., 2013).

NimbRo OP is an autonomous robot football player (i.e. *RoboSoccer*) participating in the RoboCup TeenSize competitions (°Wiki (h), 2013). The robot expresses movement and locomotion coordination with its visual perception to perform and score. Its logic is driven by pre-programmed behaviours and in case it falls to the ground, it is capable of righting itself to the standing position and to continue playing (Allgueuer et al., 2013). The robot's outfit is skeletal and despite an unnatural gait it has a stable omnidirectional walk (Missura & Behnke, 2013) which, combined with its perception skills and behaviour control, open opportunities to further R&D (Missura et al., 2012; Schwarz et al., 2013; Stroud et al., 2013). The designers of the NimbRo OP have made its software open-source (i.e. available to anyone for use and development) for further R&D and scientific share.

Table 5: Examples of Companion and Educative Robots

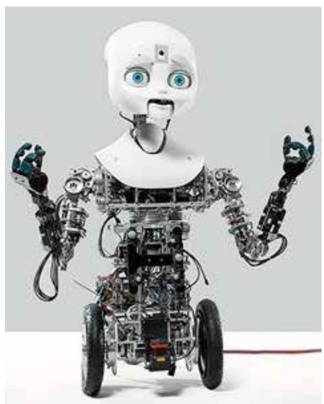
 **Figure 26**: Pleo (*026)	 **Figure 27**: Paro (*027)
 **Figure 28**: iCat (*028)	 **Figure 29**: PaPeRo *mini* (*029)
 **Figure 30**: Kaspar (*030)	 **Figure 31**: NEXI (*031)

Figure 32: iCub (*032)

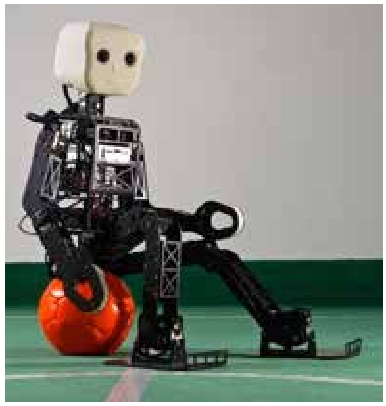


Figure 33: NimbRo (*033)

Kanda et al. (2012) show how a teleoperated anthropomorphic robot, which exhibits social behaviour, can be used to teach children to build and program basic toy robots and to stimulate children's skills and improve their own social behaviours. An example of educative robots, which can be assembled and programmed, is the Mindstorms NXT 2.0 (Baichtal, 2013). Kanda et al. (2012) remark that the added value of this type of social robots lies in its acting as an emotional and intellectual facilitator to children's self-motivation in their endeavour towards higher achievements.

2.2.5 Advanced Robots

These robots are developed to execute complex tasks and though some of their features are seldom perceived by the generic public, their outcomes affect our lives through their technological support. In some cases, some of these robots are not even perceived as such. This last subsection highlights some of the most advanced robotics that have not been addressed in the previous four subsections.

On the one hand there is motivated scepticism regarding the quantitative dimension of the *robot era's* impact on our societies but on the other hand many relevant and specific breakthroughs have been achieved during the last decade. Kusuda (2002) stated that, and this still holds true today, "*no matter how nicely the mass media reports "Humanoid age is here!" it is yet to come. However, motivated by the enthusiasm, a lot of humanoid research is now going on and alongside this new accomplishments will come out which human beings should take advantage of. However, the author considers that humanoid robots cannot be the sole goal of robotics. It will be a necessary result of future robot technology where affinity to human beings is an absolute MUST*".

Autonomous driving cars are being studied and R&D prototypes for further research are available from Mercedes Benz (°Zolfagharifard, 2013), Nissan (°Iliaifar, 2013), Google (°Fisher, 2013) and Tesla (°Carroll, 2013; °Bloomfield, 2013). For some time intelligent navigational systems have been the focus of the research community (Di Lorenzo et al., 2009; Ong et al., 2011) that wishes to determine a more holistic solution to the navigations' goal achievement and robotic decision-making procedure. The Mercedes-Benz S500 Intelligent Drive recently drove autonomously for over 100 km in Germany (from Mannheim to Pforzheim). The intelligence of the robotic car is supported by a multitude of sensors scattered around its body for various purposes (proximity and locomotion sensors, sensing other vehicles and people moving along the road etc.), cameras (one dedicated to traffic light reading), GPS for own localisation, precise digitalised road maps and a radar. The robotic car is capable of deciding on routes, keeping safe distances and manoeuvring along trafficked routes in urban or countryside areas in order to reach a defined destination (°Nedelea, 2013; °Edelstein, 2013). A human can intervene in case the robot hesitates. Understanding traffic might seem simple to those who aspire to drive skilfully but it is indeed a scientific discipline applied to intelligent systems (Assadi & Emmerich, 2013) as in the case of robotic cars.

The *eBee drone* is a light flying robot used in mapping and terrain exploration. The robot can fly with autopilot over large areas (°eBee, 2013; °Treacy, 2013) but it can also be radio-controlled. The robot, an unmanned aerial vehicle (UAV), is capable of an autonomous landing procedure, assessing both wind directions and strength. Its optical sensor allows it to estimate the correct distance to the ground. During flight the robot takes HD pictures that are used to represent the photographed area in 2D and 3D maps. The resolutions of the pictures are between 3 and 9cm per pixel (depending on the flight height) and the interpolation of the adjacent pictures basically allows a quick return of the existing territory image thanks to photogrammetric software. The robotic drone uses a GPS system and terrain sensor to move around, following the instructed flight path for up to 45 minutes at a maximum speed of 45km/h (°Hoopes, 2013). The variety of existing UAV is such that their physical dimensions, features, purposes, sensorial skills and flight autonomy (ranging from a few minutes to some days of flight time) greatly vary (°AIAA, 2011). UAV communication systems research has focused on ensuring successful collaborative frameworks for multiple drones (Bian et al., 2013) thus increasing the efficiency and security of data collection. Usually the UAV drones are used in low altitude flights (a few hundreds of meters) but some versions can go above 5 000 meters, as in the case of the °Orbiter (2013). The production of this category of robots is expanding rapidly due to their reasonably low cost (when compared to the equivalent manned planes) and the possible applications of the drones. Studies are being conducted on navigation and orientation systems and possible alternatives are being considered, as in the case of skylight polarisation combined with robotic omnidirectional vision (Shabayek, 2012) which would improve the independency of the drones from third navigation systems (such as GPS). A relatively exhaustive list of worldwide available UAV is available from The American Institute of Aeronautics and Astronautics (°AIAA, 2013).

Martian exploration rovers (from the Middle English word "roven" which means moving around, wandering) are autonomous and remote-controlled locomotion robots intended for analysis and exploration works (with testing skills) to explore the surface and the atmosphere of the planet Mars. The *Curiosity rover* is provided with ten investigation instruments including tools capable of executing chemistry and mineralogy laboratory tests, x-ray tests for spectrography plus various tools to search for volatile compounds (Leshin et al., 2013; Edgett et al., 2012). The robot has 17 cameras (one is a 3D camera) of which four are used for navigation purposes, 8 for hazard detection and one is located at the end of its arm (°Popolo, 2012). This rover is the first of its kind as it possesses such a developed geochemistry laboratory on-board (it includes a laser to vaporise materials for composition studies) for rock, soil and atmosphere analysis (Grotzinger et al., 2012; °NASA, 2013). The rover Curiosity needs to be operable from great distances and it also needs to be both light and robust and this has driven R&D into one of the most advanced fields of remote controlled robotics. The robot is capable of surveying large Martian areas, basically capturing any kind of pictures (from microscopic to panoramic views) that can be processed into intelligent upgradable databases for geological studies (Schreckenghost et al., 2012) whilst the robotic mobile laboratory can execute given scientific tests (Blake et al., 2013; °Lakdawalla, 2012).

The *JEROS* (Jellyfish Elimination RObotic Swarm) robot kills jellyfish and it works autonomously both individually and cooperatively, coordinating its actions with other robots in a swarm strategy (Kim et al., 2012; °Kaur, 2013; °Ackerman (b), 2013). Problems related to the escalating presence of jellyfish in coastal areas (including the reasons why and who is responsible) have long been examined (Richardson et al., 2009) and despite some environmentalist concerns, the danger posed to humans and maritime infrastructures is on the increase. The robot possesses a GPS, surface navigation means, a camera for surface area scanning and a slicing mechanism to destroy the jellyfish. A particular algorithm allows the robot to individuate the jellyfish and to activate a strategy to trap and destroy them (Kim et al. (b), 2012).

Pictures of the above robots are given in Table 6.

For technological reasons, the present state of robotics to the general public, seems to provide limited possibilities for advanced HRI. Short and middle term industry's cost-profit reasons are among the investment limiting factors as well as the generic public's limited interest and awareness of the value that interactive robots add to everyday life. Nevertheless, the social awareness of robotics' role in society is promoted by the emerging technologies and related studies (Howlader, 2011). The slow but steady penetration of robotic presence in everyday life constitutes a revolutionary technological wave known as Pervasive Robots (°Rouse, 2013). Robots are increasingly designed in forms that are capable of supporting the human perception of friendliness and respond to human behaviours in terms of interaction, functional interpretation and robotic communication skills (Dominguez et al., 2008). Arsenio (2003) envisioned that these robots would be integrated mechanisms for social interactions, autonomous navigation and object analysis. Recent research and technological development in pervasive robotics support the integration of e-learning and behaviourism into robotics to boost the robotic work and interactivity redefinition. These types of robots, defined as *teachable robots* (Matuszek et al., 2012), can be taught new tasks and learn from humans' behaviour. Natural languages can be used to instruct more advanced robots while their sensorial skills allow them to acquire information regarding their environments, task execution or interaction with people. All the while these robots are learning and refining their own behaviours by processing and interpreting all data via artificial intelligence (for examples see Baxter robot, LS3, Pleo, Paro, iCub, iCat and others in this Section 2.2).

Table 6: Examples of Advanced Robots

	
Figure 34: The Mercedes Benz S 500 Intelligent Drive (*034)	**Figure 35**: eBee drone (*035)

 **Figure 36**: Curiosity rover (*036)	 **Figure 37**: JEROS jellyfish killer robot (*037)

2.3 Human Robot Interactions

From the vast sector of R&D in HRI, some concepts and research principles are presented which highlight *what*, *how* and *why* plays (or should indeed play) a positive role in a proper human-centred designed robot. Obviously, the interest in educative robots and human learning behaviour drives the choice of criteria for the material presented in this section because it is impossible to deeply understand the human role and learning attitudes in HRI without having an understanding of the human behaviours' causes and reasons.

The design of a robot interface (which humans perceive visually or metaphysically) meant to support HRI should take into account the human behaviour, needs and limitations in relation to keeping and maintaining such interactions. Argall and Billard (2010), pointing to the human centric design principle, state that "*when considering robot operation around, and interaction with, those who are not robotics experts, the interpretation of natural human intentions becomes particularly relevant...Regarding the deployment of robots within novel human environments, especially those that are public, sensors with high spatial resolution and complete coverage of the robot body will be particularly valuable for the interpretation of human intentions*".

2.3.1 Cognitive Science, Psychology and Sociology

Studies and research on e-learning efficiencies and the contributing interconnected cognitive, psychological and sociological elements show a variety of factors that determine the potential success of a learning/teaching system. O'Regan (2003) pointed out in his study on "Emotion and e-learning" how cognition and emotions are interconnected and particularly how negative feelings, raised by unfriendly interfaces, cause repulsion. He remarked that the learners' frustration is often associated with the technology's failure, both in the areas of efficiency and operability, and concluded that "*emotions play a critical role in the* *teaching/learning process and that this role must be addressed in both the theory and practice of teaching and learning. Exactly what this role is and how it can best be dealt with is an area still requiring much exploration, particularly as new technologies become an integral part of that process*".

Dirkx (2001) correlates emotions and learning and places emotions in a central role in the human learning process. He says that "*personally significant and meaningful learning is fundamentally grounded in and is derived from the adult's emotional, imaginative connection with the self and with the broader social world. The meanings we attribute to emotions reflect the particular sociocultural and psychic contexts in which they arise*" and concludes that "*by approaching emotionally charged experiences imaginatively rather than merely conceptually, learners locate and construct, through enduring mythological motifs, themes, and images, deep meaning, value, and quality in the relationship between the text and their own life experiences*". Picard et al. (2004) express their concern at the lack of accounting affect or ignoring it as a relevant drive element in the learning process and remark the need for constructing a strategy to introduce affecting learning as an interconnected element to the cognitive process. Despite certain differences regarding their viewpoints and approaches, Picard et al. underline their "*shared goal of redressing the imbalance between affect and cognition, and between theory and practice, to bring balance to the science of learning and to its technologies. The greatest advancements in the science of learning will require the engagement of multiple perspectives*".

Fink (2012) warns against the over use of anthropomorphism in HRI because, despite the appreciation for the social interaction with the robot, it might raise too high human expectations which the robot cannot fulfil. According to Fink, there seems to be a culturally sensitive tendency to attribute a human mental model to a robotic system that behaves or expresses itself as human-like which explains why "*especially humanoid robots evoked more reluctant and negative responses than robots with a pet-like or more functional shape*" (Fink, 2012). DiSalvo et al. (2002) list three design principles needed for a functional robotic system: "*The need to retain an amount of robot-ness so that the user does not develop false expectations of the robots emotional abilities but realizes its machine capabilities; the need to project an amount of humanness so that the user will feel comfortably engaging the robot; and the need to convey an amount of product-ness so that the user will feel comfortable using the robot*". In other words, robotic anthropomorphic elements should be balanced by robotic evident compounds.

Groom et al. (2009) analysed some patterns of people's developing self-extensions into robots (in their test cases they used anthropomorphic and car robots) and how they perceive and attach values to such robots. They conclude that their findings "*provide further evidence that people perceive humanoid form as an indicator of unique identity and are less prone to treat the robot as an extension of the self. Perceiving the humanoid as a unique identity rather than a self extension may explain why people perceived the car to have a better personality than the humanoid*". In this light the human mind associates anthropomorphism with an individual accountable counterpart, thus granting it more interactive rights than a functional robot which in turn can be more easily used and manipulated.

2.3.2 The Role of the Brain in HRI

The interconnectivity between the physiological and psychical behaviour, that contributes to the cognitive learning process, is well defined by Ferro (1993). He gives an analysis of the brain functions and presents its interdependencies as a triune control system for physical activity, emotion, and cognition. He stresses how strategies that take into account the affective element would produce a relevant effect on the learning process. Among the affecting elements that contribute to improved learning are listed self-awareness, a positive self-concept and own trust (i.e. confidence). In his words, the creation of a motivational attitude comes from a set of strategies that use the affective domain to boost the cognitive processes and hence "*in terms of brain function, the limbic system interprets these strategies as desirable. Its messages involve the neocortex and create eustress with the attendant hormones, which cause the individual to rise to the challenge*" (Ferro, 1993).

Krach et al. (2008) examined the brain function of people while interacting with various types of partners (computer partner, functional robot, anthropomorphic robot and human partner) to determine the level of *Theory of Mind* (also known as ToM, which is the neural attribution of intentions and desires to others). In their experimental study they conclude that *"the results demonstrate that the tendency to build a model of another's mind linearly increases with its perceived human-likeness. Moreover, the present data provides first evidence of a contribution of higher human cognitive functions such as ToM in direct interactions with artificial robots*" and "*the degree of human-likeness of a counterpart modulates its perception, influences the communication and behaviour, biases ''mental'' state attribution and, finally, affects cortical activity during such interactions. Here we show that this modulation is linear, thus the more a vis-a-vis agent or entity exhibits human-like features, the more we build a model of its "mind"*" (Krach et al., 2008). Therefore, there is a different form of brain activity, more demanding but potentially also richer on a cognitive level, when dealing with anthropomorphic robots than in the case of dealing with generic robots or other computer embedded systems. This neuropsychological potentiality for social interactions should be balanced and in the words of Krach et al., *"this finding would thus suggest that the exterior of a robot should mirror its interior in that a more human-like looking robot should exhibit also more human-like behaviour*". Chaminade and Cheng (2009) underline that "*anthropomorphism is not limited to the robot's appearance and motion: interactive robots' behaviors also matter for interacting with humans*".

Gazzola et al. (2007) conducted a study using brain functional magnetic resonance imaging scans (fMRI). The examined volunteers observed similar human and robotic actions (pictures and videos). The fMRI scans highlighted the activities of the mirror neuron system (parts of the brain responsible for associating own actions to the observed actions of others as if they are carried out by the own self, hence creating a model representation). Gazzola et al. point out that the human brain reacts to the robotic actions as if they are perceived or not as meaningful (i.e. is there a goal in the robotic action?) despite the per se action performance and regardless of the human likeness of the robot. Concerning the brain's behaviour, they remark that "*the mirror system was activated strongly by the sight of both human and robotic actions, with no significant differences between these two agents*". The analysis of the data showed that the brain mirror system ceased to react to the robot's repeated single actions (i.e. the repetitive robotic actions stopped activating the mirror neuron system). It appears that the perceived lack of unpredictability in witnessed actions leads to strong habituation and low mirror neuron system reaction.

2.3.3 Robot's Behaviour and Features in HRI

Research work has been conducted in HRI on humanoid robots in order to study human reactions and perceptions in relation to robotic functionalities and appearances. Robots can be designed to express behaviours and personality. Even though some works stem from specific studies on robotic structures and environmental circumstances, there are research outcomes that are eligible to generalisation and further applications to other R&D cases.

According to Rousseau et al. (2013) arm gesture and mobility in an anthropomorphic robot increases the users' interactivity as long as they are not perceived as a threat. Feil-Seifer and Matarić (2009) say that "*the presence of a robot inherently affects a user's sense of privacy*" and further remark that "*because of its synthetic nature, a robot is perceived as less of a privacy invasion than a person, especially in potentially embarrassing situations*".

Broadbent et al. (2013) have conducted a study on the value that people attribute to humanlike faces in a robot. The robot that they used (a healthcare robot) was perceived as being more intelligent and mindful when displaying a 3D human face on its screen. They say that "*ratings of eeriness were significantly associated with the impression of personality; in particular, higher eeriness was related to perceptions of being less sociable, amiable, and trustworthy for the robot with the humanlike face display*". This points out that the more humanlike the features of the robot, the higher human expectations of its socialisation skills. Regarding this aspect Feil-Seifer and Matarić (2009) state that "*realistic robotics introduces new complications to social robot design and it has been implied that anthropomorphism has a negative influence on social interaction when the robot's behavior does not meet a user's expectations*". Fink (2012) remarks, in her analysis on anthropomorphism and HRI, that people react more positively to robots that display human characteristics (behavioural as visual) than toward robots that possess pure functionality.

Via sophisticated algorithms, robots can learn behaviours and adapt themselves to environmental situations and to specific HRI. Argall and Billard (2010) have conducted a review on tactile HRI and set a framework analysis for possible use and applications in future robots. They remark that "g*iven the expectation of robots operating around humans, and therefore human presence around robots, exploiting the knowledge and abilities of a human is a practical approach for producing robot behaviors. Touch is one form of communication through which a human can transfer knowledge to a robot. Comparatively little work to date has addressed how human touch might be employed to produce robot behaviors.*"

The work of Bertneck et al. (2007) underlines that people interacting with a robot have an attitude of associating intelligence and agreeableness to its perceived *animacy* (i.e. being alive), regardless of its outward appearance. In a later study by Bertneck et al. (2009) anthropomorphism, animacy, likeability, perceived intelligence and perceived safety are identified as the main principles that could successfully guide the design of an interacting robot. Schaefer et al. (2012) identify the robot's intelligence (whether real or presumed) in the human visual perception as the first factor to influence its trustworthiness for potential interactions.

2.3.4 Interface Design and Interactive Learning

Modern approaches in HRI interface design for interactive learning owes much of its human centred strategy to epistemology works conducted by Piaget (for an overview on his works see °Bond & Tryphon, 2007) and Papert (1980). Piaget is a key figure in *constructivism*. Constructivism (i.e. the psychological process by which an individual constructs own knowledge and intelligence) places the learner at the centre of the cognitive processes where, by acquisition of the instructional data and its transformation into individually relevant forms, the learner builds the mental models, or schemata, of the perceived reality (Riegler, 2012). Papert (1980) is among the first to identify computers and computer embedded systems with their potentialities as tools of the interactive learning processes (Papert, 1994). He is the initiator of *constructionism* (Papert, 1987 ; Papert, 1990, Papert & Harel, 1991), an epistemological theory on self learning strategy in physical interactions. Papert and Harel (1991) provide an introductory meaning of "*learning-by-making*" to constructionism and say that "*Constructionism —the N word as opposed to the V word– shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning*". According to Piaget (see °Bhattacharya & Han, 2001; °McLeod, 2009) learning happens as a process of *adaptation* to physical and mental stimulation via *assimilation* (the mind uses mental structures to assimilate any new elements or experiences) and *accommodation* (the mind reworks existing mental models to adapt to the new elements or experiences). Papert extends this learning process to an interacting and constructive behaviour that involves the external world to own self (Papert & Harel, 1991). Martin and Briggs' (1986) book on the affective and cognitive domains interconnect the affective and cognitive strategies to the learning efficiencies. Learning can be casual but the best learning happens via instructional design strategies.

MacDorman and Ishiguro (2006) say, in their sociological impact assessment of anthropomorphic HRI, that scientists should be motivated to design more realistic humanlike robots, urged on by the possibility of learning more about human behaviour. Learning is a key factor in promoting human interpersonal communication and this can similarly work in HRI (MacDorman & Ishiguro, 2006). Learning and cognitive stimulation in HRI can also occur in the absence of natural language utilisation. Le Maître and Chetouani (2013) conducted experimental tests and analysis on how a Wizard-of-Oz teleoperated robot (for more information on the Wizard-of-Oz interface design, also see Hindriks et al., 2011 and Beaudouin-Lafon and Mackay 2003) affects in a triangular interaction (person-computer-robot) elderly people's cognitive activity. These people suffered from mild cognitive impairment. In the case of Maître and Chetouani (2013) the robot's behaviour was designed based on pre-tests wherein a therapist took part in the triangular interaction (i.e. person-computer-therapist). The robotic behaviour, with its sounds and non acoustic actions (movements and light signals), positively influenced people's decision processes and engagement. The robot's presence increased the social awareness and cognition in the tested people (Le Maître & Chetouani, 2013).

Miloseva and Lehtonen's (2006) study on learning in the digital era shows how the process of learning is strongly influenced by the social interpersonal relationship and the emotional sphere. This appears even stronger in *informal learning* where interactions and communication between individuals are prominent.

Arkin and Brooks (2007) say that "*it is well supported that non-verbal communication is an important mode of human interaction, it will also be a useful component of interaction between humans and humanoid robots, and that behavioral overlays will be an adequate and scalable method of facilitating this in the long term*". Concerning the design of anthropomorphic assistant robots, Graf et al. (2002) say that communication, interaction and collaboration between robots and humans should occur in a natural and intuitive way. They say that "*human friendly interfaces involving all human senses and communication channels are essential for efficiently programming and instructing the robot, which is in turn the basic requirement for an effective and flexible use of robot assistants*" (Graf et al., 2002). Arkin and Brooks (2007) say that the proxemic component in the HRI is an important factor in the "*spatial nature of non-verbal communication*" which is related to the interpersonal distances and that it should be taken into account for study and assessment in HRI.

Works in psychology relating to the dimension of affection, its role and effects in learning, evaluation assessment and judging behaviours show how emotions play a relevant part in cognitive processes (Gawronski & Mitchell, 2014; Ditzfeld & Showers, 2014; Lerner & Keltner, 2000). Positive affects provide means for improved cognitive processes while negative affects hinder the cognitive processes in the same circumstantial conditions (Haagera et al., 2014). It is a huge mistake to ignore the role of affections (i.e. emotions and feelings) in learning behaviours, especially since there has been sound research in this area (Kort et al., 2001). Any instructional design that aims to facilitate learning in HRI should take *affection* into consideration.

Mori (2012 [1970]) defines *the uncanny valley* (read *eerie valley*) as the gap that exists in the human perceiving affinity towards anthropomorphic robots when these become too human, but still miss the perfection of similarity. Considering the knowledge gained from various fields of research which explore efficiency in HRI, particularly human-anthropomorphic robot interactions, stating that an increased human likeness in robots would cause discomfort in human interactions (as in Mori, 2012) is somehow too simplistic. Chaminade & Cheng's (2009) considerations towards bridging this *uncanny valley* seem to be supportive of solutions to design future anthropomorphic robots that would be deemed acceptable social partners to humans. As seen in this sub-chapter many factors should be taken into considerations when analysing and designing HRI. There are elements related to expertise, experience, cultural background, educational factors, personal and collective presumptions, individual perceptions and situation that influence, both positively and/or negatively, human behaviour in the interactions (Norman, 2002). In addition, it should be noted that behaviours are historically not of granitic crystallized nature and tend to change over time.

3 Research Method

This chapter describes the methodology adopted in order to answer the main research questions introduced in Chapter 1, subsection *Case Study Research*. It also describes the research related analysis used to define the prototypes' design principles and developments as well as their implementations and the evaluations of their test cases.

3.1 Methodology Approach and Research

In terms of sociological theory, this research uses the functionalist paradigm set forth by Burrell and Morgan (1979) based on a matrix with two dimensions (the nature of science as subjective-objective dimension; the nature of society in terms of a regulation dimension: the sociology of radical change and the sociology of regulation). The research is further based upon a matrix with four paradigms (these being Radical Humanist, Radical Structuralist, Interpretive and Functionalist) as expounded in the "*Four paradigms for the analysis of social theory*" (Burrell & Morgan, 1979). The analysis and evaluation of the results of the Robo-eLC test cases provide concrete information used to define people's behaviours and learning correlations and hence generalise interaction and attitudinal rules.

3.1.1 Prototyping

The purpose of prototyping is to explore and assess the usability and functionality of a product (a real or a virtual consumer good) without having to support the full production costs and the risks inherent to its possible efficiency failures (Szekely, 1995). This approach can be applied to both software and hardware design and production (Beaudouin-Lafon & Mackay, 2003). By acquiring information and data analysis regarding the prototype product's usability and user experiences (Szekely, 1995; Beaudouin-Lafon & Mackay, 2003), designers and developers can accordingly research best product strategies. A prototype model is seldom intended to be a perfect final product because its scope is to study the design, development and implementation processes and iteratively evaluate its efficiency and functionality as perceived by the users (°Sauter, 2014; Beaudouin-Lafon & Mackay, 2003). Norman (2002) shows how the lack of prototype design and testing often results in products failing their functional expectations. The design of the Robo-eLC and the TSS prototypes was conducted using a refining iteration that allowed for a user centred approach (Holtzblatt, 2002) to improve and ameliorate the prototypes towards their intended final stages.

3.1.2 The mixed qualitative and quantitative research method

When using *qualitative research methods,* researchers tend to build knowledge on given phenomenological cases, studying the sociological data and behaviour of people in order to interpret participants' views and hence define the meaning they attribute to the phenomenon (Creswell, 2003; Denzin & Lincoln, 2003; Merriam, 2002). The approach to and type of questions asked in qualitative research methods vary according to the field in which the research is being conducted; all fields' methods make use of interviews, observations and documents (Merriam, 2002). The researcher, responsible for data collection and analysis, seeks for meaning and understanding of the phenomenon following inductive data analysis processes and, in so doing, produces a rich description of the phenomenon (Merriam, 2002). Qualitative research methods can allow cross case comparisons and analysis; the researcher identifies the phenomenon contextualised setting factors (Johnson & Onwuegbuzie, 2004).

In *quantitative research methods* the researcher tests theories through well-defined hypothesis and structured predetermined questions, collects numeric and statistical data (the measurements must be objective) to analyse and define the relationships between the case factors and verify the validity of the hypothesis (Creswell, 2003; Merriam, 1998). Quantitative research methods are prone to produce generalised research findings and the research results are relatively independent from the researcher (Johnson & Onwuegbuzie, 2004).

The pure quantitative research method relies mainly on the collection of *quantitative data* while the pure qualitative research method relies mainly on the collection of *qualitative data* (Johnson & Christensen, 2007); any combination of these two methods generates a *mixed research method*. Johnson and Christensen (2007) underline that the mixing of qualitative and quantitative research methods can lead to an infinite number of permutations. In the mixed methodological designs, at least one quantitative method and one qualitative method are utilised in the phases of the research process either concurrently or sequentially at the data collection, data analysis, and/or data interpretation (Onweugbuzie, 2002). Creswell (2003) says that "*a mixed methods approach is one in which the researcher tends to base knowledge claims on pragmatic grounds (e.g., consequence-oriented, problem-centered, and pluralistic). It employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand research problems. The data collection also involves gathering both numeric information (e.g., on instruments) as well as text information (e.g., on interviews) so that the final database represents both quantitative and qualitative information*". The mixed qualitative quantitative research methods allow for a triangulation in the research approach and the converging of results and evidences to strengthen the test cases' conclusions (Johnson & Christensen, 2007).

The quantitative and qualitative data contained in this research was collected both concurrently and sequentially. The collected quantitative data provided users' information and preferences that integrated into the qualitative data and the opportunity to assess the generic and specific interaction behaviours. Further analysis and case comparisons were conducted through qualitative analysis at the end of each test case and at the end of the research work. At the end of each test case, the qualitative content analysis was transformed into quantitative data (Reeves, 2000).

3.1.3 Design Experiments

This research, according to which goals qualify development research (also known as *design experiments* (Reeves, 2000) or *formative research* (Barab & Kirshner, 2001)), focuses on creating a supportive learning behaviour approach in fundraising robotic systems and defining a set of fundraising robot design principles for future development endeavours (see *The goals of design research* in Botha et al., 2005). As an applied research work (van den Akker 1999; Reeves 2000) this thesis is intended to solve problems faced by individuals and groups (Reeves, 2000) in HRI, specifically as regards the process of participating in fundraising activities. Being that this research is concerned about the scientific fundamental understanding of the Robo-eLC HRI phenomenology and the technological aspects which the Robo-eLC can be developed into, this work falls within Stokes' *Pasteur's Quadrant* of the Quadrant Model of Scientific Research (Stokes, 1997). In Stokes' words the Pasteur's Quadrant "*includes basic research that seeks to extend the frontiers of understanding but is also inspired by considerations of use*" (Stokes, 1997).

The characterising boundaries within which this development research has evolved are:

1. taking into consideration the complex HRI factors in user's contextualised environments (Holtzblatt & Beyer, 2013),
2. using the existing know-how and theoretical frameworks in HRI, Finnish historical RoboBeggars and fundraising systems to design and then develop a viable Robo-eLC,
3. evaluating all methodologically collected data of the tested Robo-eLC and accordingly refine the HRI learning environment to achieve the optimal interactive configuration, and finally
4. defining a set of specifications and heuristics for the future design and developments of fundraising anthropomorphic robots.

The research approach governing this work's design experiment is schematically expressed with the iterating and refining loop illustrated in Figure 38. Each single phase of the loop possesses its own distinguishable order and timely sequences. The results gained in phase 5, *Evaluation of the collected data and definition of design principles,* have a transversal influence on the other four phases of the loop. Reeves (2000) highlights the refinement aspect in developmental research in his diagram, reproduced in Figure 39. The phase *Documentation and Reflection to Produce "Design Principles"* in Reeve's diagram (Point 4.) is part of phase 5 in the Robo-eLC refinement research loop (Figure 38). The research loop was iterated 6 times (see Figure 40 for an illustration of the Robo-eLC research loops and enhancement phases' timeline).

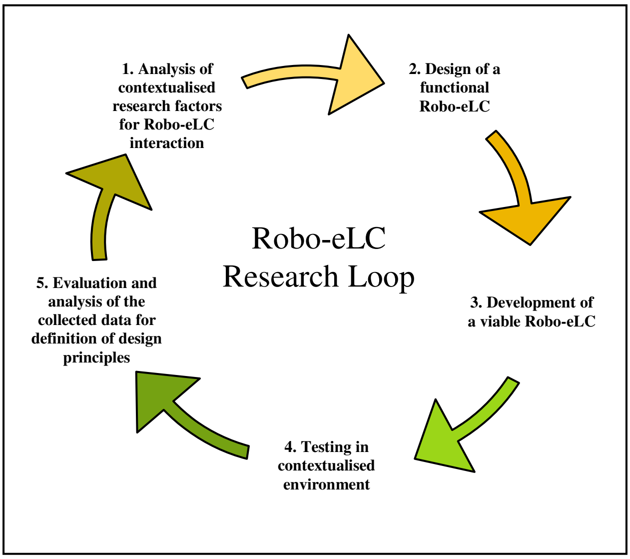


Figure 38. Development Research for Robo-eLC

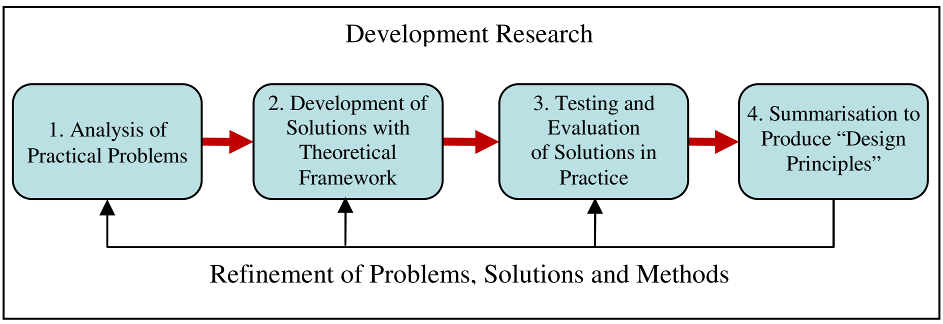


Figure 39. Reeve's Diagram on Development Research Refinement Approach

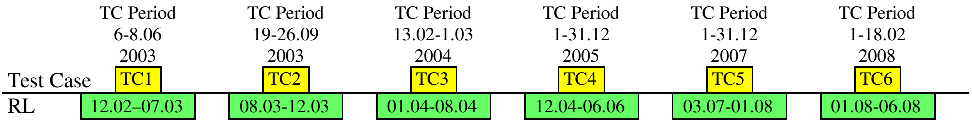


Figure 40. The Robo-eLC enhancement Research Loops (RL) and Test Cases (TC1, .., TC6)

The research questions, governing this work (Chapter 1 Subsection *Case Study Research,* page 7), are presented in Table 7 with an overview of how and where they have been dealt with:

Q1) What are the elements that make an eLC-robot a convincing interlocutor to humans?

Q2) What are the robotic embedded ICT elements that contribute to the human understanding of poorly known fundraising concepts and ideas?

Q3) What elements pose a threat to the comprehension/learning processes in human - Robo-eLC interactions?

Q4) What are the roles of the cognitive, affective and psycomotive domains in the designing of the Robo-eLC anthropomorphic robot?

Table 7: Research Questions: Answering and Reporting

Research Question	**Method Used**	**Focus Points**	**Output Data**	**Chapter or Section**	**PAPER**
Q1	Literature review, experiments, UF, UBF, interviews, observations	Test cases' evaluations and Robo-eLC Research Loop	Sets of rules for the design of future Robo-eLC	1 2 3.2 4.3 5.1	I-VI
Q2	Literature review, Test Cases evaluations	HRI, Robo-eLC functionality and efficiency	Sets of rules for the design of future Robo-eLC	2.1.3-4 2.3 4.2-3 5.2	I, II, IV, VI
Q3	Literature review, experiments, observations, interviews, data analysis	HRI and proxemics users' behaviour	Informative data regarding design and usability of Robo-eLC	2.1.4,6 2.3 5.3	I, V
Q4	Literature review, experiments, UF, UBF, interviews, observations	User's behaviours and HRI analysis with Robo-eLC and InfoKiosk	Sets of rules for the design of future Robo-eLC	2.1.3-6 2.2-3 5.4	I, III, IV, VI
Recommendations	Analysis of further R&D needs	HRI in the fundraising sector	Strategy for future research	6	I IV V

3.2 Description of the Robo-eLC research approach

This subchapter describes the Robo-eLC research approach and its phases which are constituent of the adopted methodology. The research loop (Figure 38) was applied following Reeve's Refinement Approach (Figure 39) to evidentiate the problems, seek for solutions and refine the applied method. While the research loop followed a rigorous sequential evolving phase approach, the outcomes of phase 5 "evaluation and analysis of the collected data for definition of design principles" of each test case had a direct impact on the other research phases.

The start of this research project dates back to 2002 when the first focus group examined the research potentialities for a HRI research related to e-learning and e-commerce connected to a feasible replica of the traditional Finnish *vaivaisukko* (Finnish word meaning *begging-man* and referring to a wooden statue used for charity fundraising; plural: *vaivaisukot*). Interdisciplinary researchers (with backgrounds in computer science, pedagogy, engineering, sociology etc.), third sector representatives and church leaders were members of the focus group from the very beginning. The focus group was, in time, enlarged to include people with other expertise including deacons, church ministers and bankers.

3.2.1 The contextual analysis

Interviews were conducted with the focus group to frame the historical and social value of the vaivaisukot (Santaholma, 2001; °Fides, 2002; °Wiki (a), 2013). The analysis and transferability of the original fundraising concept were researched, taking into account the newly emerging necessities and the geographical, historical and social environments. Analyses were conducted on robotic appearance and efficiency from two perspectives: firstly the academic research point of view and secondly the fundraising point of view. Resemblance and appeal factor were studied in relation to the cultural factors. Studies regarding the known problem areas in HRI and the possible effects of digiphobia and technophobia in relation to accessing programmes or computer embedded technology, were also conducted.

The target population, taking into account the research contextual analysis, was adults (people interacting with the robot were expected to have the freedom to donate money) and non digi-literates (assumption of novice or beginner skills in interacting with advanced technological equipment) regardless of educational background, gender or age. If on the one hand fundraising tends to address the same groups of the population in order to keep their motivation to donate alive, on the other hand any expanding fundraising strategy must dare to reach out to new potential groups of the population. Analysis was thus carried out on standard users' requirements (Norman, 2002) and in particular their need to know, the behavioural learning paradigms, the ease of use of the interfaces in terms of user-centred design principles and the motivational support of the systems (Mondi et al., 2007; Swan, 2004). Human perception of a robotic presence and own safety in relation to HRI were also analysed (Alami et al., 2006; Schaefer et al., 2012) in relation to proximity factors.

Location analysis for the Robo-eLC pointed out that the robot would be used in open spaces or in areas where it could easily be accessed and subsequently it was decided upon which materials and what structural system should be adopted to guarantee some degree of durability, resistance and ease of transportation. Even though the robot was intended for adult use, it was noted that it would also be accessible and used (at least for learning interactions) by teenagers and children. In addition to these considerations, the robot test cases were expected to be conducted in remotely located places and hence some level of mechanical disassembling and easy assembling had to be studied. The analysis of continued and discontinued robotic functionality led to take into account the eventuality of resetting the robotic system (in case the researcher or technician was absent) and this, in turn, posed problems with the programme design.

The collection of data and metadata from the test cases, which were meant to be used in this research study, set out considerations as to the forms of data collection. It was important that the process of obtaining the necessary information, emanating from the expected results of the test cases and analyses, was conducted according to a suitable methodological approach. Subjective and objective information collection procedures were considered in the contextual analysis of the HRI and this lead to the design of a repeatable and comparable data collection system.

The usability tests of the Robo-eLC robot were mostly scheduled to take place at fundraising events on behalf of developing countries. A wider analysis of the existing fundraising needs and end-beneficiaries highlighted that women are the group most in need as they are the main bearer of the material and occupational brunt of poverty in developing countries throughout the world (De Haan et al., 1998; Hulme et al., 2001; Harcourt, 2001). This analysis led to the design of the anthropomorphic robot with female features. It is enlightening to note thatonly one female vaivaisukko statue (which should more correctly be called *vaivaisakka* or, in old Finnish, *vaivaiseukko*, i.e. begging woman) survives in Finland (Figure 41). This as opposed to the 107 examples of male vaivaiseukot (Santaholma, 2001; °Etelämäki, 2000).

Figure 41. The vaivaisakka at Soini village (*041)

3.2.2 The Design Specifications for the Prototype Model

The anthropomorphic Robo-eLC robot needed to physically resemble and recall the vaivaisukot in people's imagination so that it would be easily recognisable as a modern version of a fundraising vaivaiseukko. The robot also needed to be able to collate information by means of visual, aerial and hypermedia devices that could create and process fundraising target data, statistics, graphics, sociological data, and other specific interactions. Secure and easy money transfer operations had to be guaranteed, allowing those individuals interacting to feel safe throughout the HRI processes. Supporting learning means had to be created to meet users' needs and expectations (Huang et al., 2002) but also introduce and augment new factors of e-learning (Thorme & Root, 2002; Pritchett, 2002; Mondi et at., 2007) about fundraising targets and goals, the reasons for the fundraising, the targets fixed by the local community and the reasons why it is ethical to donate money to help people in need. It is indispensable to the success of the HRI process that some sort of gratification and personal feedback to the users should be rendered by the robot (Mondi et al., 2007; Swan, 2004) as this encourages users to donate and reinforces donor behaviour (Van den Berg et al., 2006).

With regard to its physical appearance, both the structural and aesthetical appearance of the robot had to be considered. If one recalls that the dimensions of most of the vaivaisukot vary between 150 and 180cm approximately (Santaholma, 2001; °Kirjastovirma, 2014) and keeping in mind the need for a small statured Robo-eLC (important for the HRI related to the cultural background and the attitudinal approach of lay people), its height was set at 150cm. The hull of the robot's main body had to keep some seemingly anthropomorphic proportions, as in general the vaivaisukot do have proportionate bodies regardless of their height (°Rastipukki, 2014). The hull, made of light metal and provided with a secured locking door, had to be spacious enough to contain a computer with a keyboard and a mouse, two loudspeakers, power transformer and various electronic and mechanic equipment. Movements were limited to the hand, the right forearm and the head of the robot which all combined to fulfil its needs for motion related factors (i.e. the robotic physical communication means necessary for it to be perceived as a "live" partner) and robustness. The physically visible anatomical parts of the robot had to be as anthropomorphic as possible.

The money-collecting functionality had to operate in combination with the e-learning functions so that users could easily complete the donation process and be encouraged to use the Robo-eLC again. A touch screen interface was devised as a means of direct communication in the HRI as visual data could flow and users' inputs to the robot would occur. To avoid digiphobia, a full-graphic and intuitive donation interface was designed. The use of "plastic money" (i.e. bankcards) added features to the hardware (namely a bankcard reader necessary to process donations).

An internet connection with a simple graphic interface and domain limitations (for uploading and downloading material) was designed to access more online information on fundraising issues, to upload/download material for the further development of some features of the robot and eventually to facilitate remote access to some of its modules.

Table 8 shows the basic technical specifications for the Robo-eLC hardware at a glance.

Table 8. The Robo-eLC Hardware Specifications

ELEMENTS	TECHNICAL INFORMATION
Processor	Pentium III 500Mhz
RAM	128 Mb
ROM	256 or 512 Kbytes
Motion	2 AC motors for head and hand movements
Hard Disk	10 Gb
Bank connection	Account-to-account instant transaction via bankcard and/or credit card and transaction receipt printer
Internet connection	ISDN
Screen	Touch sensible screen
Keyboard	Simple waterproof keyboard

Loudspeakers	2 integrated loudspeakers in the robot
Power	External
Extension elements	The robot can be "expanded" by similar modules to create a multiple beggar robot for more simultaneous users.
Size	Base Square Side: 55 cm Height: 150 cm
Weight	About <30 Kg

The Robo-eLC's software was intended to concurrently control the motors and the speech of the robot, making the speech as natural as possible and controlling the software itself (i.e. the connections of all of its functioning). All connections and main functionalities (i.e. the robot's architecture) of the Robo-eLC are depicted in Figure 42.

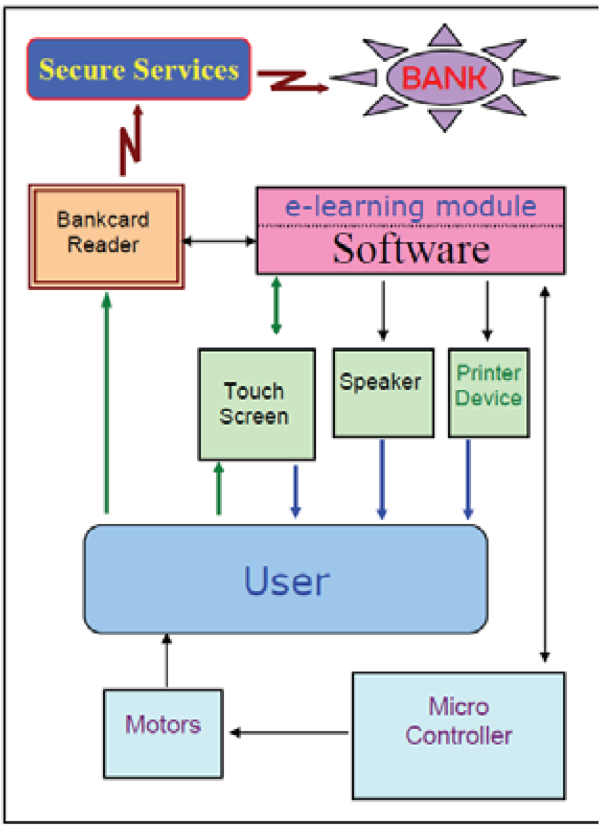


Figure 42. The Robot's Architecture

The Software. The software controls the other components of Robo-eLC. It contains the educational software (e-learning modules) that educates the user concerning current issues of poverty, famine and the needs of the goal countries.

The Touch Screen. Users mainly interact with the robot through the use of the touch screen. All the information is displayed on the screen and users select the operations or navigate within the e-learning modules by touching the screen at the appropriate places.

The Card Reader. The card reader reads the magnetic tape of the card and uses this information to charge the right bank account. The amount of money being donated is decided upon by the user and relayed to the software which controls the card reader. The card reader handles (by means of its GSM connection) the donation from Robo-eLC to the bank via a secure service.

The Secure Service ensures that the money transfer, from bank to bank, is confidential and secret in order to protect and guarantee the individual's confidential bank data.

The Micro Controller and the Motors. Motors facilitate the robot's arm and head movements and are controlled by a programmable microchip (a micro controller) which receives directives from the software through a serial port. These commands are interpreted in the micro controller and the motors are controlled accordingly. The robot needs to have some gestures that are also connected to the sound card and speakers.

The Sound Card and the Speakers. The sound card and speakers allow the robot to talk or give some aural feedback to the users.

The Printer. The printer prints a receipt after the donation has been processed so that givers are in immediate possession of physical evidence that the donation has occurred.

3.2.3 The Development of the Robo-eLC

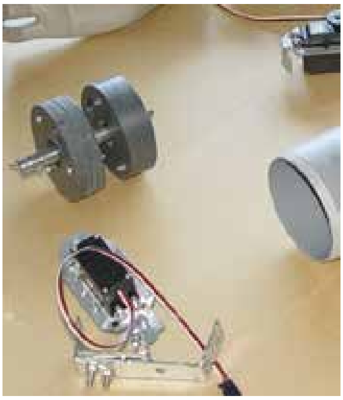
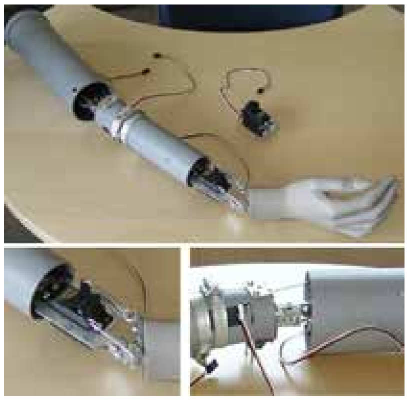
Cooperation with the Science Park of Joensuu (*Joensuun Tiedepuisto Oy*) was initiated in late 2002 and this provided the researcher with a link to the technical and entrepreneurial sector and to specific technical services. In Spring 2003, based on my design and drawings of the robot, the vocational college of North Karelia (*Pohjois-Karjalan Ammattikorkeakoulu*) produced a set of aluminium plates and structural beams to be assembled into a main body (see Figure 43 and 44). In the meantime, the robot's mechanical movements (Figure 45 and 46) were addressed by mechanic and plastics experts from the local school of Learning Centre (*Oppimiskeskus*), the Adult Learning school of North Karelia (*Pohjois-Karjalan Aikuisopisto*) and the Pohjois-Karjalan Ammattikorkeakoulu. All DOF were obtained by axis rotations, via servomotors, which were inserted inside and at the extremities of the pipes (Figure 46). The head and hands were originally parts of a mannequin which was donated by the local clothing store, Kekäle (a nationwide clothing company), and these were connected via rotating axis to their supporting plastic pipes (Figure 46).

By Spring 2003 all electronic, metal and plastic parts were ready and each component had been successfully checked or tested. In addition the metal brackets, meant to fasten and protect the bankcard reader and the touch screen, were timeously produced by the Pohjois-Karjalan Aikuisopisto (Figure 47). All parts were assembled and connected in late May 2003 (Figure 48).

Throughout late Winter and early Spring 2003, an agreement had been reached with the local offices of Osuuspankki bank and the security transfer data company, Point Oy, to access the transfer security code which would allow a semi-automatic money transfer mechanism. The purpose was to allow donors, interacting with the Robo-eLC, to donate a fixed amount of money "in a swipe" without having to enter their security pin. The final transfer coding which allowed for such operations asked the donor to follow the simple onscreen information and make a choice in the donation module where icons represented the monetary value (see Figure 49).

Figure 49: The Donation Module. A "one-touch & one-swipe" donation system

Table 9: The making of the Robo-eLC

 **Figure 43**: The robot's assembled base with locking door	 **Figure 44**: The robot's base and torso
 **Figure 45**: Rotation axis framed in neoprene disks through bearings	 **Figure 46**: The servomotors connected to the rotating axis and a hand
 **Figure 47**: The safety brackets holding the touch screen and bankcard reader	 **Figure 48**: Assembling the robot

The robot was programmed to follow a schema in its interaction with potential donors. The flow chart in Figure 50 provides an interaction overview as well as the expected times between actions in the HRI. The proposed timing schema, according to which the HRI was tailored and users' expected actions estimated, is better explained in Figure 51. The very first event in which the robot was used is depicted in Figure 52.

Learning modules composed of textual, graphical and aural data were created according to the information received from the non-profit organisation Suomen Lähetysseura and the local Lutheran Churches (*Joensuun Evankelis-Luterilaiset Seurakunnat*). One researcher at the University of Eastern Finland gave the robot a voice by recording a set of sentences and messages (to be used by the Robo-eLC in its operating phases) in her own voice at a studio in the Science Park.

The robot was dressed according to the social nature of the fundraising event. The dress and appearance of the robot was changed, or adapted, for each fundraising opportunity. On one occasion it was even painted to render its appearance more dramatic.

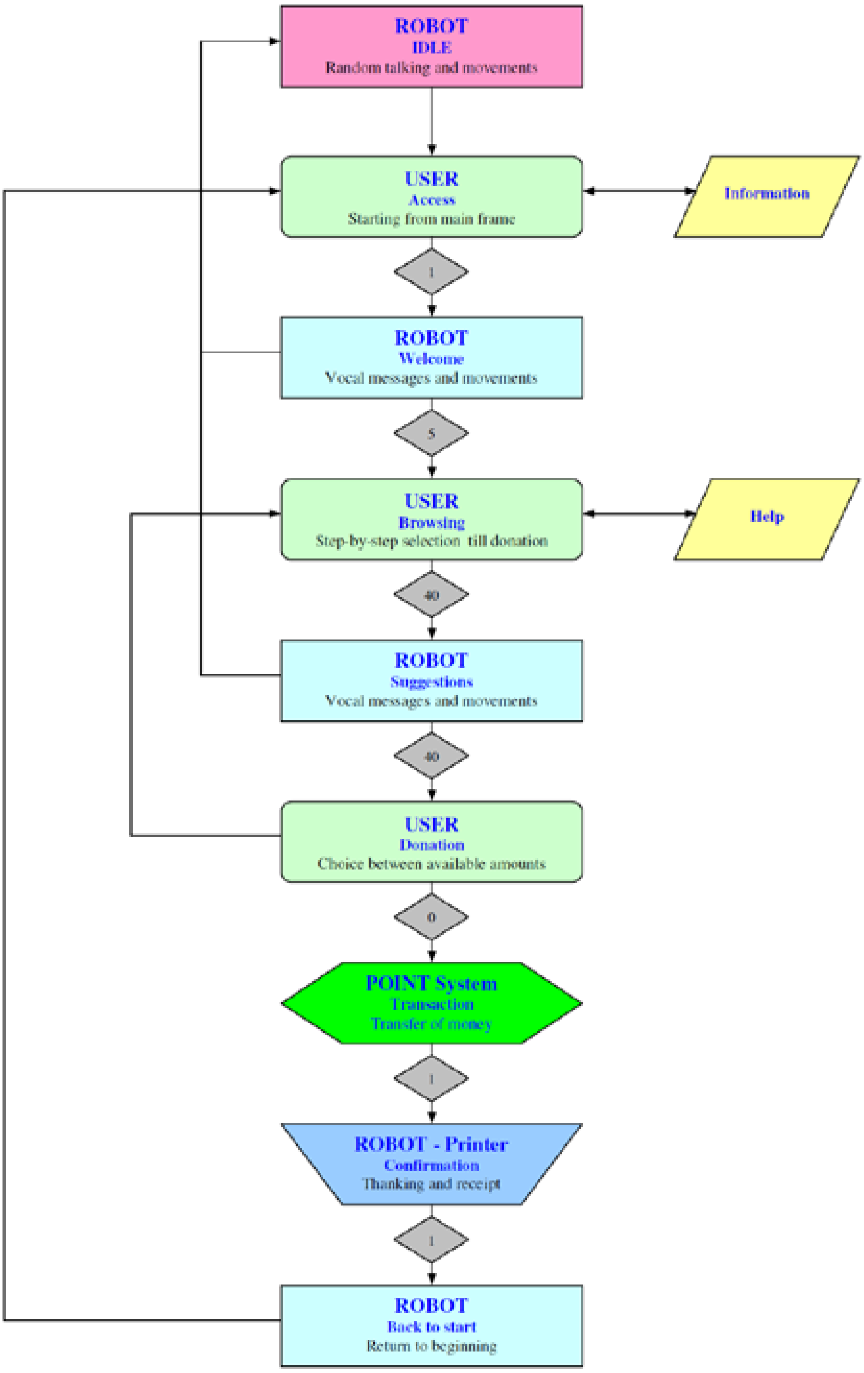


Figure 50: The Robo-eLC Flow Chart

Phase #	User	Speakers	PC	Movements	Screen	Bankcard	Printer	Idle
1	Standby	Invitation	Random actions	Random	Globe 3D			On
	3 or more random talks: "Dear sirs and ladies, please help me and the people I am carying for…" "Please, could you help me? Come and see what is the situation…"							
2a	Access to PC by *touch*		Count time 10"		Globe 3D			
2b		Welcome	Open programme	Greetings	Welcome screen			
	1 or more random talks: "Thank you for starting this ….."							
3	Read "Welcome"		At End of count: #1	Greetings	Welcome screen			
4a	Press "Information"		Count time 20"		Welcome screen			
4b	Read "Information"	Talk "information"	At End of count: #1		Information screen			
4c	Press "Back"		Restarts count		Information screen			
	1 or more random talks: "Well done….."							
5a	Press "Start"	Say "*Well done*"	Count time 10"	Arm gesturing	Welcome screen			
5b	Read "Choices"	Choice advices	At End of count: #1	Arm gesturing	Choice screen			
5b	Press "Back"		Restarts count		Choice screen			
6a	Press "Help"		Count time 10"	Hand movement	Choice screen			
6b	Read "Help"	Talk "help"	At End of count: #1	Head movement	Help screen			
6c	Press "Back"		Restarts count		Help screen			
7a	Choice number "x"		Count time 10"		Choice screen			
7b	Read "Shock"	Say "*Did you know?*"	At End of count: #1	Head/Arm random	Shock screen			
7c	Press "Back"		Restarts count		Shock screen			
8a	Press "euro"		Count time 15"		Shock screen			
8b		Appreciation		Head nodding	Shock screen			
8c		Time expires in 15"		Arm movement	Donation screen			
8d	Press "Back"	Encouragement	Restarts count		Donation screen			
	1 or more random talks: "You have chosen to donate to ….."							
9a	Choice of donation				Donation screen			
9b			At End of count: #1		Donation screen			
9c	Donation	Appreciation (1,2,etc)		Appreciation	Donation screen			
	1 or more random talks: "It is something very important that people like you donate ….."							
10a			Connection to bank		Please Wait screen	Money Transfer		
10b		Money Sound	Confirmation OK		Please Wait screen	Donation done		
	1 or more random talks: "You know what what? Your donation has been registered and it will be used as…see in internet the information ….."							
11		Thanking	Close connection	Thanking	Thank You screen		Printing receipt	
12a			to *Welcome screen* #3					
12b			Count time 10"		Welcome screen			
12c			At End of count: #1		Welcome screen			

Figure 51: The Robo-eLC HRI phases and talks

3.2.4 Running the Test Cases

In 2003 and 2004 the fundraising robot was tested in four cases for different periods of time, varying from a few days to some weeks. The purpose was to collect as much qualitative and quantitative data as possible at each event which would then be analysed in an effort to supply answers to the main research questions posed in Section 3.1. The robot was dressed and adapted for each fundraising event so that it would be visually appealing to potential users. The voice modularity of the robot kept the same structure throughout all the test events. The graphical user interface (GUI) was modified according to the needs of the fundraising event. The unexpected refusal of some users to interact with the Robo-eLC in the Noljakka church (Test Case 4), led to the development and testing of the comparable fundraising Touch Screen System (TSS) to further analyse users' behaviour in HRI in the context of a sacred spiritual domain. Two TSS test case events took place in 2007 and 2008.

Test Case 1. In June 2003 the Robo-eLC was tested for the first time during a missionary event in Joensuu (°Iltalehti, 2003). Thousands of people participated in the event, most of whom had been previously exposed to and/or were committed to charity and aid support activities. The robot was thus supposed to test its skills in stimulating peoples' learning behaviours and encouraging them to donate to three targeted countries (Ethiopia, Mongolia and Venezuela). The robot was located in an inner walkway, close to one of the main entrances to the conference hall of the Arena stadium. The Robo-eLC was dressed as an old poor Finnish lady.

Figure 52: The Robo-eLC in use in June 2003

People from the research team were present throughout the duration of the test case to answer questions and guide peoples' use and interaction with the robot. Users were asked to complete an evaluation questionnaire. This questionnaire remained basically unchanged for all the test cases (including, for response comparison reasons, the TSS testing cases, apart from some technical or clarifying elements). People were allowed to freely interact with the robot and research team members' interventions were kept at a minimum (e.g. some people needed initial guidance on how to swipe the bankcard on the magnetic reading head of the bankcard reader).

Test Case 2. In September 2003 the Robo-eLC was tested in the Osuuspankki bank, Joensuu. The users in this case would most probably be bank customers and possible passersby as the bank had a corridor connecting the two sections of the building in which it was situated. The fundraising event aimed to collect money for aid purposes in Tanzania and the Robot was dressed in traditional clothing to resemble an African Tanzanian girl (Figure 53). The researchers were not present for most of the time as the bank upheld office and customer privacy policies. The special test case environment (a mixture of private/public conditions and security surroundings) was considered a good opportunity in which to verify people's self-motivation in initiating a HRI. In addition, the bank personnel discretely monitored activities around the robot. The modular interface was basically the same as in Test Case 1 with some adaptations to provide for the new fundraising goals. People were informed of the presence of the robot (articles in this regard appeared in local newspapers) and were free to interact with it at their own volition.

Figure 53. The Robo-eLC in the Osuuspankki, Joensuu (*053)

Test Case 3. In early Spring 2004 the robot was tested in the Kupittaa mall, an urban shopping mall in Turku (the main town on the southwest coast of Finland) which is frequented by many people. The OP Bank Group (one of the largest financial services groups in Finland, known by their acronym OKO) cooperated in the research project by funding the basic transportation costs of the robot and by allowing it to be placed next to their bank in the Kupittaa Mall. Even though the robot was placed outside the bank offices, it was never the less close enough to be monitored by the bank personnel. The robot was set up on the side of the walkway of the main hall of the mall so that it would be visible and accessible to the thousands of people who frequent the mall daily. The Cancer Association of South-West Finland (Lounais-Suomen Syöpäyhdistys or LSSY in Finnish) was the designated beneficiary of the robot's fundraising activities and, in exchange, the organisation provided cooperation in collecting data (users' feedback and behaviour assessments) which was used towards the research analysis. The robot, dressed as in Test Case 1, wore a jacket with the LSSY logo - fundraising campaign (Figure 54) printed on it.

Figure 54. The Robo-eLC in the Kupittaa Mall

Test Case 4. In December 2004 the Robo-eLC was tested in the Lutheran Church of Noljakka. The fundraising event was organised to help refugees or displaced people trapped by negative economic circumstances in Angola, France, Germany and Israel. The Suomen Lähetysseura (the *Finnish Missionary Association*) together with the local church cooperated in providing material and data for the robot's learning modules. The Finnish seasonal pre-Christmas emotional attitude and the high attendance usually noted at churches during this period of the year lead to expectations of rich users' feedback and behavioural data. Inside the church premises, the robot was placed in such a way that attendees could not pass by without noticing it, although room for interaction was allowed. The robot was dressed identically as in Test Case 1 and its GUI was adapted to the test goals' situation. The robot was introduced to each service's audience and local newspapers reported on it. Researchers were present at each church event to monitor the robot and give help if needed.

Figure 55. The Robo-eLC in Noljakka Church

Test Case 5. The Software of the Robo-eLC was integrated into the InfoKiosk (a multimedia pillar kiosk, see Figure 56) and an avatar was introduced to substitute the physical component of the robot. This avatar, called RoboAvatar, was a visual substitution for the physical movements of the Robo-eLC. The basic structure of the e-learning modules of the robot was preserved in the InfoKiosk, specifically its voice and donation phases remained the same as in the robot. All functionalities of the touch-screen remained in the InfoKiosk. Test Case 5 (as Test Case 6) verified the validity of analysis and evaluation of the feedback obtained with the Robo-eLC, particularly in substantiating reasons for some people objecting to the robot's presence in the church. This test case occurred in December 2007, just before Christmas. The fundraising effort was in support of radio and telecommunication projects which aim to provide information and education to vast areas in Near East and North Africa. The Suomen Lähetysseura and the local Lutheran Church took care of the informative material used by the InfoKiosk and/or provided maintenance back up. The InfoKiosk, with its Touch Screen System (TSS), was publicised and introduced to the church attendees by the church ministers and officers. The expected high frequentation of the church and similar usage circumstances (as in Test Case 4 with Robo-eLC) were the main reasons for conducting this test in the same environment. I followed the main events in these two test cases (Test Case 5 and 6), collecting behavioural data and recording observations.

Figure 56. The TSS in the InfoKiosk in Noljakka Church

Test Case 6. This test case, featuring the InfoKiosk, took place at exactly the same location and used the same physical environment as Test Case 5 (i.e. within the Noljakka Church, at the identical same spot). The test occurred in February 2008 and the fundraising was to assist the Suomen Lähetysseura in its on-field work with various communities in Angola, Israel, Senegal and France. The modular e-learning components were updated while the other components remained the same as in Test Case 5. Since the test case environmental conditions were similar to that of Test Case 5, the differentiating element was the time period (post-Christmas time) and thus the potential users were less emotional. The motive in conducting a crosscheck test of the InfoKiosk was so that the combined evaluation analysis from this test case, Test Case 5 and the available data from Robo-eLC test cases would give rise to a triangulation verification of HRI hypothesis which emerged during the research.

3.2.5 Evaluation

The evaluation data used in this research was in part quantitative and, in part, qualitative. In Test Cases 2 and 3 the quantitative data was poor but in Test Case 3 the qualitative data was rich.

The quantitative data comes from users' feedback (UF) via multiple-choice questionnaires (PAPER II) based on Likert's scale of five answer values (Likert, 1932) which are apt to study behaviours (Likert, 1932; °Uebersax, 2006, Kislenko & Grevholm, 2008). A test case user feedback form (UF), with its English equivalent, is enclosed in Appendix A. Likert items used in the questionnaires, were kept identical and comparable throughout the test cases for corroborative reasons. The Likert scale's answering values responded to: 1 = I completely disagree; 2 = I partially disagree; 3 = I am unsure; 4 = I partially agree; 5 = I completely agree. The scales used focused on the functionality of the hardware, the influence of the equipment in the donation process and the use of plastic money in HRI and HCI donation (PAPERS I and II). The UF questionnaires included a section of three-point statement questions so users could express an evaluation/opinion regarding the Robo-eLC and the TSS. A section of the questionnaire was also dedicated to user gender, age group and computer experience. Other quantitative data came from donation figures and the metadata recorded by the fundraising systems. In Test Cases 5 and 6 the UF questionnaires were similar to those previously designed for the and UF used in Test Cases 1, 2, 3 and 4 apart from the addition of specific questions related to the new features of the RoboAvatar (PAPER III). The questionnaires focused on Robo-eLC and TSS users':

1) Gender
2) Age group
3) The functionality of the fundraising system
4) The effectiveness and influence of the fundraising system
5) User evaluations and assessments
6) The donation system application

The qualitative data collected includes the researcher's subjective observed facts (Creswell, 2003; Johnson & Onwuegbuzie, 2004) as recorded in individual user behaviour forms (similar schemes were used in Test Cases 4, 5, 6 and 7; data was collected in a non-intrusive manner and users were not aware of being observed while busy with the donation process). The user behaviour form (UBF) included the interactions of the users with their physical environment, the users' perception of the robot, the users' emotional expressions and their behaviour during the interactions. A test case user behaviour form (UBF) is enclosed in Appendix B. In Test Cases 4, 5 and 6 observation schemes were conducted (an example of this form can be found in Appendix C) and the following information was acquired and registered in the observations (PAPER III):

1) The test event occasion and its social value
2) The total number of people present and their age distribution
3) The behaviour of the people in the vicinity of the fundraising system
4) The behaviour of the forming groups of people and their actions in relation to the Robo-eLC (and later the InfoKiosk)

5) The behaviour of the individuals that approached the Robo-eLC (and the InfoKiosk)

A section of the UF was blank for users' freeform feedback. Members of the Focus Group were interviewed. The schematic interviews, related to the Robo-eLC, were conducted in April/May 2005 while the ones for the InfoKiosk were conducted in March 2008. A template for the interview questions reduced to a minimum my influence on the interviewees (via question formulation) and increased the possibilities for analysis parallels between the test cases. Interviews to further investigate users' behavioural data in a semi-structural way towards the personnel attending or responsible for the fundraising Robo-eLC and the InfoKiosk were also done.

The tools used to collect the quantitative and qualitative data were:

1) The user feedback (UF) forms. See Appendix A.
2) The user behaviour forms (UBF). See Appendix B.
3) The event observation schema forms. See Appendix C.
4) The structured and semi-structured focus group interviews.

In addition to the above, other information available included users' donation targets, donated amounts and systems' metadata.

The mixed quantitative and qualitative data evaluation focused on a three-fold analysis study: cognitive, affective and technological. The analysis results on the effectiveness of the Robo-eLC have been placed parallel to the results of the InfoKiosk (Figure 57) to give and corroborate (as exhaustively as possible) the answers to the main research questions (Introduction and Section 3.1).

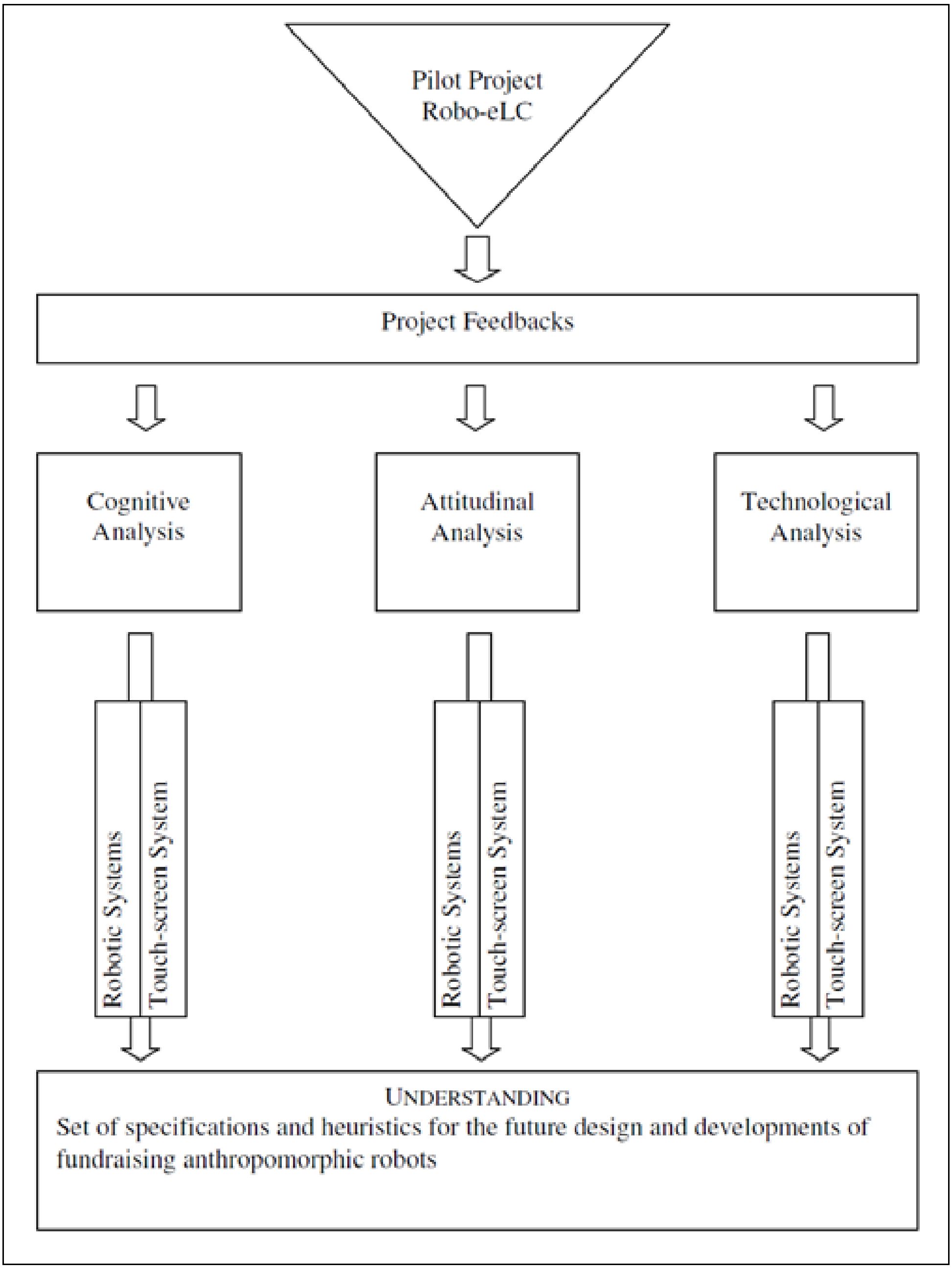


Figure 57. The three-folded research structure approach

4 The Prototype

This chapter describes, in more detail, what has already been introduced regarding the Robo-eLC prototype in Sections 3.2.2 and 3.2.3. This chapter refers to PAPERS I, II, III and V.

4.1 The Software of the Robo-eLC

This section, which aims to describe the main software structure of the Robo-eLC (and the InfoKiosk), is strongly based on PAPER V.

The software produced, refined, changed, adapted and integrated into the hardware (of both the Robo-eLC and the InfoKiosk), was the result of the work of a group of researchers and students who followed my specifications and design concept, in particular for the GUI (Graphic User Interface) and the HRI communication modularity. The design of the Robo-eLC programme (as well as the InfoKiosk computer embedded e-learning fundraising system) benefits from a structured and methodical approach that takes into account the design flexibility. An Object Oriented Design (OOD) and Object Oriented Programming (OOP) in Java coding language was adopted to address these problems (Booch, 1994; Arnold et al., 2005). In each research iterating test case it was possible to redefine the programme modules based on evaluations of the interactions that took place between users and the hardware (related metadata was also provided by each system's software). The adaptability and flexibility of the programmes, that constituted the operational base for these two systems, enabled the researchers to quickly incorporate the emerging data from the learning processes of the users, thus enabling them to refine the systems for higher efficiency.

Java programming language (Arnold et al., 2005) was used to create the software of the two fundraising hardware systems. This choice was made, among other reasons, because of the portability of the system code and it being deployable in Win32 or Unix (Arnold et al., 2005). The software of the fundraising systems connected the various modules which, in turn, interacted with one another by means of a message-passing mechanism. The kernel module was the main module of the system and it was responsible for the behaviour of the system because it regulated the function orders and commands. All components and configuration elements of the programme (of the Robo-eLC and InfoKiosk) were stored in XML files (including the user donation targets and amounts). These also included sound elements, the repertoire of possible movements by the Robo-eLC and the different attitudes and responses that the avatar in the TSS was able to convey to a user. The robot contained the feasibility for tracking users' actions and various data could be stored in the clients.xml file. This feature could be used for software debugging, intelligence improvement and for the statistical analysis of user behaviour. In addition, each time the kernel received a message or sent a command, an event was stored through the logging module which recorded it in the database. The record of the event contained a timestamp, a message originator, a message receiver and all the message parameters. Eventually it was discovered that most of this data had more value for software functionality and the statistical aspects of module behaviours than for this research purposes since most of the user' behavioural data could be collected from other sources. In any case, it was possible to examine the database log through a time of occurrence search, message originators, message receivers and session under scrutiny (PAPER V). The XML files contained paths to pictures and sounds, quantity and positioning of buttons and text information.

The Robo-eLC is an *Embedded System*: a combination of computer hardware and software with the addition of other mechanical parts, designed to perform a dedicated function (Marwedel, 2006). The Robo-eLC is a fully functional appliance which has all the necessary control systems and adaptive modules contained within it. The intelligent core controls arranges the movement of the head and the right arm, the vocal functions, the interaction with the users via the touch screen, the Internet connection and its use as well as the bankcard reader and its secure data transmission to the banks. The design of the software allowed for an easily extendable model for which the addition of new functions does not require significant changes to the existing code. This was achieved by a design method in which the system is modelled as a collection of cooperating agents (or *objects*.) The individual objects were treated as instances of definitive classes within a certain class hierarchy. In this approach, there are four design stages: 1) Identify the classes and objects; 2) Identify their semantics; 3) Identify their relationships and specify class and object interfaces and 4) Implement the design (Booch, 1994). Therefore, to extend the Robo-eLC system, some external modules had to be added or some replaced. Since several actions should happen simultaneously in the robotic system, each module had to have its own execution thread (Sikora, 2003).

The robot's intelligent behaviour is guided by a set of rules that defines said behaviour. The Robo-eLC managed itself according to this set of rules which, in this way, constituted its control centre. The rules were stored in an XML file which was loaded during the execution time. Frame-based logic was used by the robot which had several states (or conditions), each with its own set of rules. When an event occurred, the robot chose the response action according to the specific state, event and rule. An example of rule definition as used by the robot is shown in Figure 58.

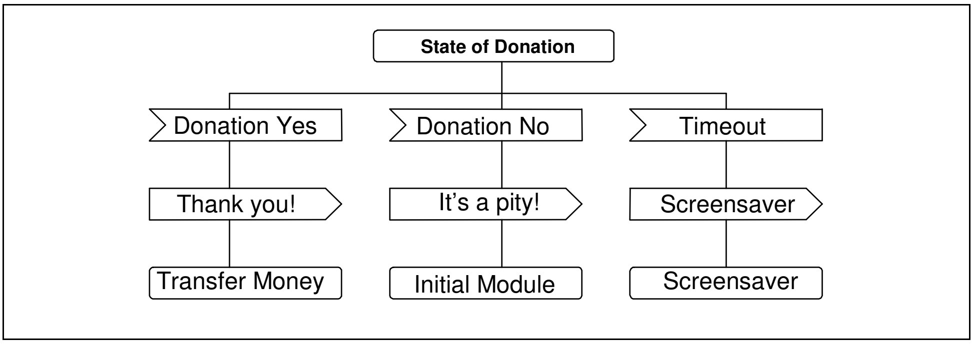


Figure 58. Robo-eLC donation events and responses

The system consisted of several main components (the system class-diagram is given in Figure 63). Each system component was an object which ran on its own execution thread. The main objects were instances of the classes that inherited the RoboThread class (Naughton & Schildt, 1999), which in turn describes common thread behaviour. Objects could interact by sending each other messages. The central object of the system was a Kernel, which was an instance of the RoboKernel class. It dispatched all messages in the system (see Figure 63).

An intelligence module managed the system. Upon receiving a message request, the Kernel checked with the intelligence module for the proper order. The intelligence module in turn looked for the available rule and after retrieving it, transmitted the data to the kernel which in turn sent the command to the appropriate component of the robot (for example to the learning module component, voice component, movement component, etc.). This solution avoided many problems related to the handling of multiple commands that could cause hang-over situations in some test cases. This allowed changing the behaviour of the system by simply changing the intelligence module. For example, adding hardware to the system would require that a module responsible for the new hardware would be developed and then some commands or events added to the intelligence module.

The internal robot systems were driven by messages. Each module could initiate a set of actions by sending a message to other modules. Message sending was prompted by some events (such as a user pressing a certain button in the GUI or the card reading had been completed successfully) or by a random action by the system to attract users’ attention. Whenever a message was sent to a certain module, before sending, the sender specified the receiver of the message. The receivers were main modules and they were addressed by string identifiers. Each module had its own message queue and they would not process all received messages, just the last one. This avoided timing problems like, for example, the robot uttering phrases out of context. A member-variable controlled this behaviour and message handling was handled in a separate thread. This allowed the robot to speak, move and change the display picture simultaneously.

The main module of the system is the kernel module. Its task was to receive an event from peripheral device modules, to request information about actions and to transmit these commands from the intelligence module to the peripheral device modules. See Figure 59 for the Kernel behaviour scheme.

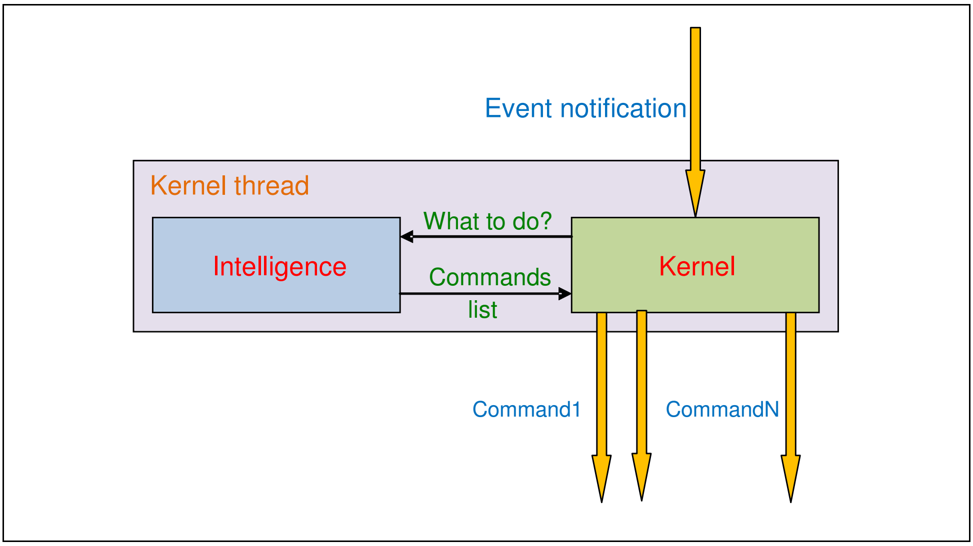


Figure 59. The Kernel behaviour scheme

The behaviour scheme of the other objects was quite similar in that they did not request any information from the intelligence module but directly interpreted commands and handled them.

The behaviour of the robot can be described as a reflex agent (Russell & Norvig, 2003), where the user action (as environment main source) causes a robotic response based on its rules and metadata. This behaviour is graphically described in Figure 60.

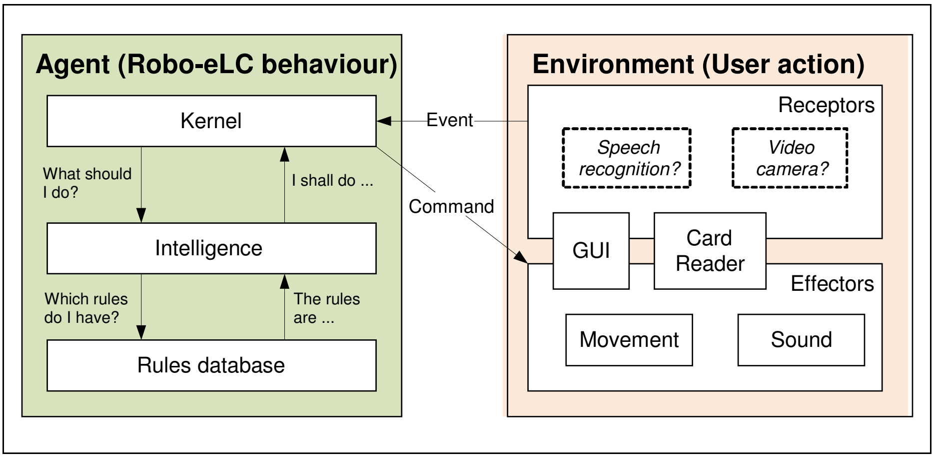


Figure 60. The fragment of the system class diagram.

The implementation of the intelligence module used an XML rules database file. This file was loaded during the system start-up. The Robot-eLC manager/operator could change the robot's behaviour according to new HRI criteria, but in order to apply such changes the system had to be restarted.

The architecture of the InfoKiosk software (Figure 61) that was installed in the multimedia pillar kiosk with its TSS interface, was a variation of the original software that was used for the Robo-eLC (PAPER I). Figure 62 shows the Robo-eLC and the InfoKiosk in the same physical environment namely Noljakka's Church. In order to substitute the physical element of the robot, an anthropomorphic avatar was integrated into the software of the InfoKiosk system by the creation of a frame distribution in the user interface (De Carlo, 2007). The avatar, obtained by animated gif each containing around 20 frames, was synchronised with the audio modules. The software components that were deactivated in the InfoKiosk included the microcontroller of the motor (because the robotic hardware had already been removed) and the internal Internet browser software. While the Robo-eLC robot interacted with users by means of movements, verbal communications and touch-screen responses, the InfoKiosk interacted with users by means of a touch screen, verbal communications and the synchronisations of the actions and reactions of the avatar.

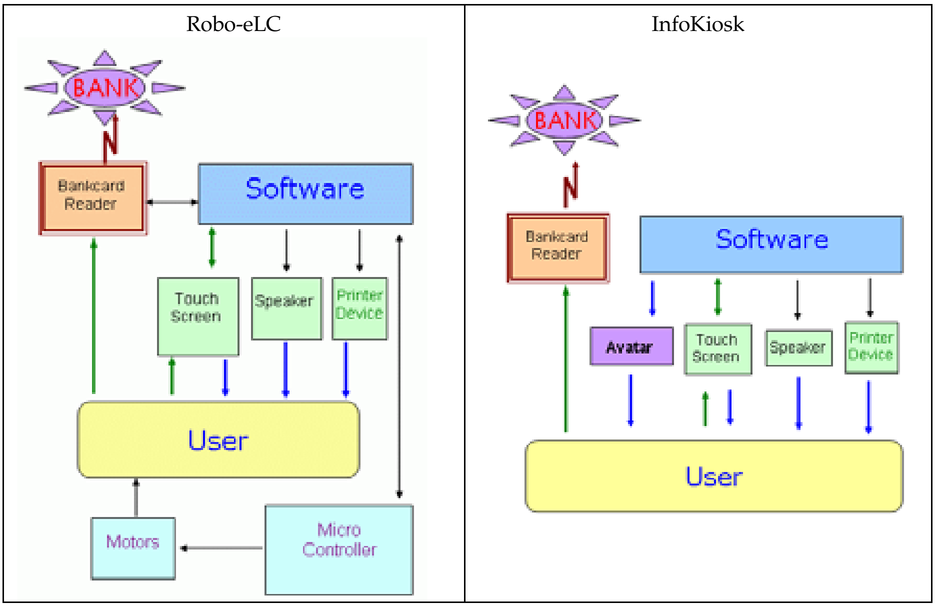


Figure 61. The Robo-eLC (left) and the InfoKiosk (right) architecture structures

Figure 62. The Robo-eLC and the InfoKiosk in Noljakka's Church

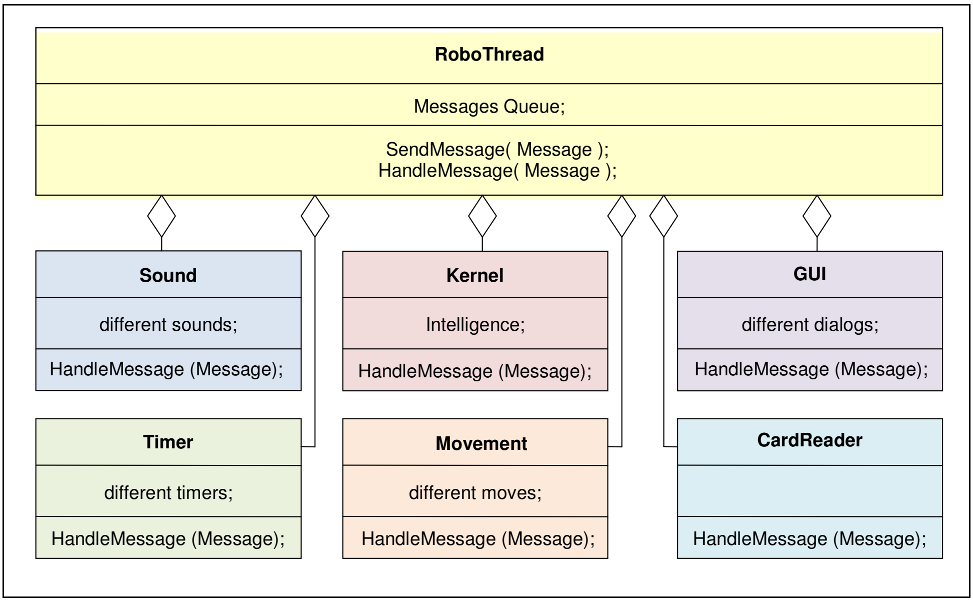


Figure 63. The Robo-eLC system class diagram

4.2 The Structure of the Robo-eLC (and the InfoKiosk)

This section describes the architecture of the Robo-eLC (and the InfoKiosk) and it is strongly based on articles by La Russa et al. (2004), PAPERS I, II and III (especially as concerns the RoboAvatar and the InfoKiosk system).

The structural elements of Robo-eLC

The main architectural elements of the Robo-eLC are the ***touch screen***, ***the motors***, ***the micro controller***, ***the sound card*** and ***the speakers***, ***the bankcard reader***, ***the printer*** and ***the software***. The software architectural element has been discussed on its own in Section 4.1. The architectural schema of the Robo-eLC (as depicted in Figure 42 on page 76) and its parallelism with the InfoKiosk is found in Figure 61. A visualisation of the two fundraising systems is given in Figure 62. The physical construction and structure of the Robo-eLC are described in 3.2.3 and can be viewed in Table 9 and Figures 52-55.

The ***touch screen*** served as the platform interface for user-robot interactions. All user inputs to the fundraising system happened via a graphic button selection. The touch screen presented the users with a selection of data, pictures and information relevant to the fundraising targets. The touch screen presented material was one of the visual components of the learning modules (the other visual component was the Robo-eLC itself). The software timed the interactions and reacted to idle and time-elapsing periods accordingly, consequently activating own modules (e.g. activating audio and/or movement modules). Users' actions were tracked through their interactions with the touch screen and the software was able to time idle periods or elapsed time between any two events initiated by a single user (Figures 50 and 51). Users had the option to select functions through the GUI (i.e. gain more information, browse within the internal learning modules, browse the internet, donate a sum of money to a selected cause or restart the interaction by returning to the main learning module) according to the information which appeared on the screen or the verbal communication of the robot. The main learning module of the Robo-eLC GUI in Test Case 1 is shown in Figure 64. The robot responded to users' actions providing information in visual, aural and kinetic forms. The Robo-eLC's software coordinated its own gestures and verbalisations.

Figure 64. The main learning module of the Robo-eLC GUI in Test Case 1

The Robo-eLC used ***servomotors*** to move its right limb (forearm and hand) and head. The motions were coordinated with the aural component of the robot. All motions were three-dimensional and were obtained by coupling two servomotors per body part movement for a total of 6 DOF. The servomotors were controlled by a programmable microchip which also had the function of dictating minimum and maximum rotations angles. The ***micro controller***, which was connected via a computer's serial port (COM1), was controlled by the robot's software. In other words, the software commanded the micro controller that interpreted the orders which were then sent to the servomotors.

The ***sound card*** and ***loudspeakers*** enabled the robot to provide aural feedback to the users. The verbal communication aspect (i.e. the aural affecting component) of the robot, combined with its ability to move, all contributed to increase its perceived anthropomorphisation. The Robo-eLC was able to communicate through a set of pre-recorded verbal sentences, information relating to its aid purposes and the goals of the fundraising activities. The loudspeakers were located in the chest and protected by metal nets. They were intentionally located in the upper section of the torso to allow the voice of the robot to emanate as close as possible to its head.

The ***bankcard reader*** had a GSM transmission capability to communicate the transaction data to the banks via secure servers (see Section 3.2.3). The data was transmitted at regular intervals and a copy of the donation registry was also available. The bankcard reader was therefore capable of reading the bankcard's magnetic tape (swiping the card through the electronic reader) and charging the chosen amount to the donor's bank account via the GSM connection. No security pin code was required for the donation (brief but very clear information was given to the donors before the donation event occurred). To avoid gross mistakes and decision process doubts, the amount and further decisions regarding the transaction were done by following certain steps. The use of icons simplified the correlation of the desired amount of money to be donated with the amount of money that is involved in the transaction itself. The electronic money transaction was facilitated by the use of active icons (see Figure 49) which represented prefixed sums, from 1€ to 100€, that could be donated. The euro banknote and coin icons provided the users with a sense of tangibility in order to heighten the donation experience. The bankcard reader was connected to the system through a serial port (COM2).

The ***printer*** was integrated into the bankcard reader and printed a receipt (a memorandum) which was issued to the user and which contained information regarding the donation sum. The receipt also showed information regarding the beneficiary of the fundraising campaign and could show more personalised information regarding the bank transaction. Even though the printer was integrated with the bankcard reader, it could easily be detached to operate through an external standard printer. For security and maintenance reasons, the integrated printer was always used.

The ***software*** (Section 4.1) simultaneously controlled the motors, the speech, the e-learning modules (see Section 4.3) and the internet connection (when available) while responding to the user, who interacted via the touch screen. The e-learning modules, managed by the software, were designed to take as much as possible of the cultural background in which the Robo-eLC was intended to operate into consideration. The text and vocal messages targeted culturally specific elements in an attempt to help bridge the cultural gaps between Finnish users and the inhabitants who would draw benefit from the donations in the targeted countries.

The begging robot Robo-eLC was designed to look like a poor woman in order to portray dire real-life situations. The robot was capable of inviting passersby to approach and use the fundraising system. The movements of the upper right limb and head were synchronised with the robot's speech and served as a stimulus to keep the attention of passersby and users. GUI's screen shots (the graphic interface of the touch screen), vocal assistance and robotic motions aided the users in their interaction and supported them by providing a supportive cognitive companion (PAPER VI). At the end of the donation process, more information was made available to users concerning the donation issues (including web addresses, some traditional data about the developing countries, collected money, etc.).

The Robo-eLC was in itself a multimodal interface for learning and donation. In the multimodal interface, four different components cooperated together, either directly or indirectly: 1) the visual interface, 2) the audio system, 3) the motion system and 4) the cognitive element.

1) Despite the fact that the software based HRI started when users' touched the touch screen, users' interaction started when becoming aware of the robot as a whole. In the HRI visual interface, users received information on what could be done in that specific phase and how to move to the next phase of the interaction. Through the use of this mechanism users acquired know-how and gained confidence to engage with the system.

2) The speech was fundamental in advising users about their actions as well as their own idleness.

3) The motions of the robot created an additional realistic element to the learning environment. People would often take notice of what the robot would do while talking and considering it as an incentive to proceed in the operations. The combination of these first three components constitutes the basic elements of the multimodal interface.

4) The cognitive element refers to the condition in which a learning activity is stimulated in users. Users are "driven" to think and to quickly come up with conclusions. For example, many users interacting with the Robo-eLC would perceive the physical stimuli of its multimodal interface as a mental model that helped them to better focus on the learning and donation decision process. It is important to note that this condition does not refer to the cognitive process itself but to the psychological environment that accelerates the reasoning processes (PAPER VI). The combination of the first three elements was intended to bring about the cognitive element, without which the Robo-eLC would have failed in its aims.

The integrated e-learning modules of the GUI were designed to motivate and raise the interests of the users so that they would become self-conscious and proceed to make a donation.

The InfoKiosk and its architecture

The software present in the Robo-eLC was installed in a multimedia pillar kiosk that was about 80 cm in diameter and 160 cm tall and equipped with electronic components and multiple connectors. This multimedia pillar kiosk became the InfoKiosk, after some modification and integration of software previously used in the Robo-eLC. For the architecture schema of the InfoKiosk, see Figure 61.

The InfoKiosk software that was installed in the multimedia kiosk is a variation on the original software that was used for the Robo-eLC (see Figure 55 for pictures of the Robo-eLC and the InfoKiosk). An anthropomorphic avatar (the *RoboAvatar*) was integrated into the software of the InfoKiosk system by the creation of a frame distribution in the user interface (De Carlo, 2007). The necessary modularity changes and updates to the GUI software and e-learning components were conducted to preserve the main structure and functionality, while keeping the same visual structured interface. Some software components were removed from the InfoKiosk software, including the internal internet browser features. The microcontroller and the motors in the original architecture were rendered dormant even though they remained present in the code of the InfoKiosk software. While the Robo-eLC robot interacted with users by means of movements, verbal communications and touch-screen responses, the InfoKiosk interacted with users by means of a touch screen, verbal communications and the actions and reactions of the avatar. The InfoKiosk used the same software functionalities of the Robo-eLC to solicit donations for different purposes by using e-learning modules and vocal communications (PAPER I).

As in the Robo-eLC the interactions with users occurred by means of a touch screen. The avatar figure was present throughout the interactions with users so that it could function as the alter ego, or virtual identity, of the InfoKiosk. The main purpose of the avatar was to encourage users to interact with the system by creating a friendly, amusing and comfortable situation in the time that it took donors to pass through the various stages of the automated learning programme, till motivated donation might occur. The successive phases of the interactions generated by the InfoKiosk were basically very similar to those used by the Robo-eLC because they both used similarly structured e-learning modules (with similar associated vocal messages and structured graphical information). Figure 65 shows touch screen interface screenshots from Robo-eLC and the InfoKiosk.

The RoboAvatar is designed to be synchronised with the e-learning modules of the software and it follows the user interactions with the system by talking and expressing emotions according to the presented situation. The avatar is capable of expressing eight different conditions: greeting (used at the beginning of the interaction and when needed to attract users' attention), standing and swinging (waiting for users' actions), happy (jumping with joy), sad (when a donation is interrupted or unsuccessful), generous (holding a gift box when users intend to effectuate a donation), bored (when the system is idle with activated screensaver) and talking (when it communicates verbally with the users). A typical behaviour sequence of the avatar is the greeting, followed by talking and then showing a gift box and jumping for joy at a successful donation (PAPER III).

Test Case 4 December 2004

Test Case 5 December 2007

Figure 65. A Robo-eLC screenshot (left) and a InfoKiosk screenshot with RoboAvatar (right)

4.3 The e-learning Modularity of the Robo-eLC

A crucial aspect of Robo-eLC is the e-learning module. The e-learning module consisted of an internal and external part. The internal part was the active multimodal system, deployed by the robot's software during the donation process. The external part was constructed in a web site and accessed via the browser integrated in the GUI. Due to the fact that most of the interactions and donations occurred via only the use of the internal part of the e-learning module, I refer to the internal part as *the e-learning* module.

The function of the internal part is to work as an empathic reminder. It reminds the user about the value of their action and its impact in the target country. In this way the Robo-eLC shows the actual needs of the countries being targeted in a concrete way. Parts of the e-learning module were meant to teach the users about some of the cultural elements of the people being aided. The goal of the internal part is to stimulate the users' comprehension of the specific needs and the potential role that they could play by generously contributing money. This is also achieved by increasing the user's understanding of the actual impact of their contributions, in other words their act of giving was anchored to the real needs of real people and concretised vivid pictures of the daily life. At the end of the donation process, counters were added to allow users to see the amounts of money that had been donated at particular times for specific targets.

The external part of the module was used to inform people about more fundraising opportunities. Due to the pure graphic interface nature of the HRI, specific web pages had to be constructed to allow touch-navigation. The internet connection was considered important to facilitate access to web learning centres in order to give enriched and recent information to the users. The robot's internal browser acted as a form with an extended timeout to access the internet (after a given time the internet connection was reset). The browser had several restrictions: 1) the address bar was absent so users were unable to type in new internet links and navigate away from the intended sites; 2) the sandbox paradigm: if a domain was not listed in the trusted domains the users could not follow the link to such domain and 3) the Learning Centres' pages constituted the only starting pages from which users could navigate to other useful links.

The Multimodal Interface (MI) of the Robo-eLC

This section is an extract of the article contained in PAPER VI.

The MI was made up of three components that cooperated, directly or indirectly. These components were the visual interface, the audio system and the motion system. Users began their interaction through the visual interface (a touch screen). Users were then exposed to an organised set of screens where they received information on what to do in the existing phase and how to proceed to the following phases. Phase by phase, users acquired knowledge and gained confidence in using the system.

The robot timed the lapses between each user action and acted accordingly. Through the inputs received via the touch screen, the robot could follow the behaviour of the users and verbally interact in a realistic way through the aural components. The verbalisations of the robot provided information to the users. This information could be related to the specific browsing action (i.e. browsing the internal part of the e-learning module) or related to the donation process. The Robo-eLC kept track of the flow of time and gently reminded the users to complete their interaction (the robot took care that an interaction process leading to a donation event would occur in a reasonable amount of time, as seen from the diagrams in Figures 50 and 51).

The movements and speech of the robot were synchronised. The two elements were synchronised by time-counting events that were dependent on users' actions (Figures 50 and 51). Depending on the user's actions, or lack of action, the robot would move or say something to help, advise or stimulate the user through the learning and donation process. The motion component of the Robo-eLC contributed a realistic element to the robotic learning environment.

Thanks to the software modularity aspects of the Robo-eLC and its Object Oriented Programming structure based on the Java language (PAPERS III and V), the core software of the robot was updated to host an avatar that would simulate and represent the Robo-eLC hardware. The new user interface was remodelled to leave room for the avatar without disrupting the existing modular basic structures for the interacting browsing buttons, test fields, photos or data (diagram, tables and so on) areas (De Carlo, 2007; Huang et al., 2002).

5 Findings

This chapter presents the answers to the main research questions (Introduction and Section 3.1, Table 7) following the three-folded research structure approach (Section 3.2.5) schematically depicted in Figure 57. The three-folded study has focused on the analysis of the cognitive, affective and technological (motor/technical) impacts of the Robo-eLC (and the InfoKiosk, for the triangulation assessments of some analysis results of the Robo-eLC) on users' learning behaviour and donation. Table 10 presents the main research questions and the related answering sections and papers.

Due to the nature of this complex interdisciplinary R&D and the looping of the test cases (Section 3.1.3) to obtain the relevant quantitative and qualitative data (Section 3.1) to support or clarify the previous test cases' results, the used instruments (Section 3.2.5) were used throughout the test cases. In some test cases (as in Test Case 3, see PAPER II) there was partial lack of quantitative data (the UF) but the qualitative data that was collected via focus group interviews (some conducted during the test cases' events and others conducted shortly after the fundraising events) and observations (UBF and proxemics[10] observations). Four interviews were conducted in a schematic form (at the end of Test Cases 4, 5 and 6) while more interviews were conducted in a semi-structured form during and after all test cases.

Table 10. The research questions and the answers' index

Research Question	**Section**	**PAPER**
Q1) What are the elements that make an eLC-robot a convincing interlocutor to humans?	5.1	I-VI
Q2) What are the robotic embedded ICT elements that contribute to the human understanding of poorly known fundraising concepts and ideas?	5.2	I, II, IV, VI
Q3) What elements pose a threat to the comprehension/ learning processes in human - Robo-eLC interactions?	5.3	I, V
Q4) What are the roles of the cognitive, affective and psycomotive domains in the designing of the Robo-eLC anthropomorphic robot?	5.4	I, III, IV, VI
Recommendations	Chapter 6	I, IV, V

[10] Proxemics is "*the study of how man unconsciously structures microspace - the distance between men in the conduct of daily transactions, the organization of space in his houses and buildings, and ultimately the layout of his towns*" (Hall, 1963).

5.1 eLC robots as convincing interlocutors

The instrument that yielded the most valuable data in answer to Q1 was the UF (the anonymous User Feedback) which used Likert scales and three-point statement questions through which users could express evaluations and opinions. This UF provided quantitative data on users' expertise, age, gender and users' evaluation on the functionality (fnct) of the Robo-eLC (technological and affective elements), the impact/effectiveness (impct) of the Robo-eLC in the donation process (cognitive related elements) and the use of plastic money (pl_m) in donation (usability and technological elements for developments). The three-point statement questions focused on users' perception of what influenced their behaviour throughout the interacting process.

The quantitative data of the UF was complemented by the qualitative data that users provided with their freeform feedback and the data that I collected via observations (users' interactions with the robot and users behaviour in its proximity) and via interviews (in a schematic and semi-structured form). Events analysis were conducted in some test cases (Test Cases 4, 5 and 6) with a descriptive form to list the place, the event type, the participants, the age distribution, the behaviour of the people around the robot (or the InfoKiosk) and the interactions concerning the robot (or the InfoKiosk).

The median and inter-quartile values of grouped questions in Likert scales from test cases are shown in Table 11. The values in the table are meant only to give an indication of the general attitudes since each single scale element is otherwise treated separately for the attitudinal evaluation analysis. Test Case 2 is missing because the UF were missing and only qualitative data was collected.

Table 11. The grouped Likert's scales values

Test Cases	**Median Value (Mdn)**			**I-Quartile Value (IQR)**		
	fnct	impct	pl_m	fnct	impct	pl_m
TC1	5	5	5	0	2	0
TC3	5	3	5	1	2	1
TC4	4	4	4	2	1	2
TC5	5	4	3	1	2	1
TC6	5	4	3	1	2	1

The quantitative data in Test Cases 1 and 2 show how there was strong consensus of Robo-eLC users on the functionality, efficiency, fundraising system approach and learning capabilities of the robot. The low inter-quartile also indicates strong consensus on such users' expressed evaluations and opinions.

The quantitative data in Test Case 4 shows how the Robo-eLC performed less well than in other cases and inter-quartile values show how there was no polarisation of opinions. In that test case the qualitative evaluation analysis showed the reasons for the low performance and fewer feedbacks.

The answer to this question is obtained by complementing each test case quantitative data with the related case qualitative data. An e-LC robot becomes a convincing interlocutor to humans by:

1) *Presence*. The robot should possess a personal, social and environmental *congruent presence* through which users can recognise and positively identify and accept it into a HRI. To posses presence the robot needs to be interactive and supportive without being threatening or strange. The simplicity of its communication means should be paired with the intelligence of its actions. The users' cognitive element is strongly dependant on how the technology succeeds to deploy the presence factor in the robot.

2) *Embodiment*. The robot should embody the idea or function for which it is intended. This is achieved by its appearance and body language which should mimic a human being if it wishes to convey its intended values through visual communication. The affective element develops according to the embodiment.

3) *Identity*. The robot should reflect a character and some sort of distinguishable behaviour should be detectable. This is achieved via profiling features according to which the robot can express itself as a recognisable individual in a personalised HRI. Technology, and its supported cognition, work together to increase users' affectivity.

The Robot-eLC partially failed its performance in Test Case 4. Most of the people avoided approaching the robot to initiate a funding interaction. The quantitative data evaluation analysis shows that users' opinions were distributed along the scale with a positive tendency but the qualitative data evaluation analysis clearly pointed out the inadequacy of the robot in a church milieu (proximity evaluation and interviews were conducted). The robot was not seen as a charity fundraiser but more as a soul-less entity, in sharp contrast with the spiritual surroundings. The InfoKiosk performed much better on this aspect of being acceptable.

5.2 Robotic embedded ICT elements for fundraising understanding

The background work to seek answers to question Q2 stems from the literature review (Sections 2.1 and 2.3) which indicated the general direction for which the robot's interface and behaviour had been designed. Implementing the design elements into the Robo-eLC, testing, analysing, evaluating and verifying for further refining in the Robo-eLC Research Loop (Figure 38) was part of the adopted developmental research method (see PAPERS I and II).

The quantitative data collected via the UF gave fundamental information on the efficiency of the GUI and the HRI for each test case. Table 12 lists the percentage of Likert's scale feedback positive scores (4+5) on the questions 1) User interface was easy to use, 2) The use of the robot was consistent, 3) Donating was simple and 4) The learning material had an impact on the chosen target.

Table 12. Users' feedback on the learning interface in Robo-eLC

Test Cases	1)	2)	3)	4)
TC1	93%	95%	95%	45%
TC3	100%	100%	100%	0%
TC4	67%	78%	55%	62%
TC5	82%	82%	85%	74%
TC6	79%	79%	83%	69%

In addition, some of the three-point statement questions provided feedback on the fundraising e-learning relevancy to motivate donation. The presented feedbacks in Table 13 are related to: 1) Did the robot considerably influence the decision to donate? 2) Was the information provided by the robot important? and 3) Was it useful to show the concrete achievements that the donation would obtain? In Test Cases 4, 5 and 6 these questions were slightly reformulated but kept a similar form and meaning. All three test cases were situated in the same church and the questionnaire similarities were an added value towards comparison analysis.

Table 13. Users' "YES" feedback on robotic help and learning material

Test Cases	1)	2)	3)
TC1	77%	68%	83%
TC3	20%	60%	80%
TC4	22%	55%	55%
TC5	75%	85%	80%
TC6	37%	96%	71%

The qualitative data for answering this question was indispensable for combined evaluation analysis together with the quantitative data. The qualitative data came from interviews of Focus Group participants who, in turn, received constant feedback by attendees and users of the robot. In addition, observation data regarding users' behaviour (UBF) and semi-structured interviews of users were conducted.

The robotic embedded ICT elements that contribute to the understanding of poorly known fundraising concepts are:

1) The *iconic representation of facts and figures* (pictures, tables and graphics) associated with the *aural elements* of the robot (the talkative communication skills as part of the robot's behaviour). The quality of the robot's voice (volume, timber and expression) has an impact on the affective attitude of users.

2) The *informative data* related to the specific needs targeted by the fundraising event. Clear, simple and open information regarding the fundraising activities motivates people to donate to the activity. The data that is presented in the e-learning modules must be straightforward and very clear, showing what the concrete impact of even the smallest donations would be. The cognitive behaviour of users is highly dependent on the form in which an e-learning element is designed and presented.

3) The *interactivity of the robot,* that which brings facts and information from a virtual world into the real three-dimensional situation in which the users participate in the HRI. To become immersed in an interaction with the "living" robot, stimulates cognitive activity. This element of technology has a strong positive stimuli in the psychomotor attitude of users as shown by quantitative and qualitative data evaluation.

Test Cases 2 and 3 presented with situations in which the robot did not perform successfully and UF were missing (TC2) or limited (TC3). The interviews of Test Case 2 revealed that the robot failed, basically because it was standing on the wrong place. Very few people approached the robot and none left a UF (the fundraising organisation informed us that they had received very little money, which the robot metadata confirmed). This was attributed to the novelty of the Robo-eLC design and the cultural dissonance of bank and charity activity plus the fact that most of the attendees present were focussed on activities completely divergent from donating. In Test Case 3 the failure was initially as a result of the robot having to be restarted every now and then and also to the fundraiser's concept of using the robot as a totem (PAPER II). Despite this, the available UF and the conducted interviews provided rich data for evaluation analysis. Test Case 4 is more pertinent to the next section 5.3.

It is know that the phenomenon of digiphobia (the irrational fear of digital things which in the case of the Robo-eLC takes on the form of technophobia) easily affects people that have had poor experiences with or limited understanding of digital equipment, especially when one fears that making a big mistake (whether real or presumed) would cause some sort of damage (to own self or to others). During the test cases it was sometimes witnessed that people were afraid of approaching the robot, despite the safety of the testing environment and the presence of professionals. In cases where the person was determined to start an interaction, the results were very surprising to the user. Relief and self-confidence replaced fear and mistrust. The reason for this turn of events was the simple and intuitive design of the GUI which was designed based on user-centred concepts (Norman, 2002).

5.3 Threatening elements for human learning in HRI

For question Q3 the qualitative data in the test cases was richer than the quantitative data towards defining and explaining the reasons for HRI failures with the Robo-eLC. The quantitative data provided an indication of users' evaluation but left out the specific and explanatory reasons (which only detailed interviews or observations could fill). Deeper understanding of human behaviour and attitudinal approaches with technological artefacts, and specifically with anthropomorphic robots, was derived from the literature review. These insights provided a better understanding of the test cases' results. The observations of people's behaviour (as individuals or groups), the schematic and semi-structured interviews and the UBF provided the data for evaluation and it highlighted the following:

1) The acceptance of the Robo-eLC as a potential interactive partner is bound to its *proxemics*. This proved true (i.e. the robot being neglected or rejected) in Test Cases 2 and 4. People attach a positive, a neutral or a negative value to the presence of the Robo-eLC according to their pre-existing behaviour (or *modus operandi*). Despite the purpose of the fundraising robot, it is the potential users' preconceptions that dictate if the robot is suitable or not in a specific environment. This can happen regardless of whether the environment and the Robo-eLC might technically and theoretically work well together (such as fundraising in a church). It is the affective factor that dominates the cognitive and psycomotive ones.

2) The low quality design of the GUI can reduce or hinder the users' satisfaction in the HRI. Lack of interdisciplinary information to tailor the e-learning modules or poor natural skills to design the e-learning modules on behalf of the Robo-eLC tutor can lead to a low quality e-learning experience for the robotic user. The consequence of this is that interest in the interaction is lost. Users' cognitive faculties need to be stimulated by a pleasant interactive interface, whether virtual in the internal e-learning modules or physical in the robotic appearance.

3) The functionality of the robot as a piece of hardware has an impact on its trustworthiness. There were two technical factors that especially raised users' concerns. The first of these related to the money transfer. It was important for users to be sure that the money transfer was safe and secure because the simplicity of the donation module was a new and surprising element to their experience. In addition, people were unfamiliar with swiping a bankcard in a magnetic reader and this was, for some, quite problematic (some users had to try several times before understanding the correct way). The second concern related to the robot's motions and physical behaviour. While on one side it was not always important that all motions of the Robo-eLC were synchronised with its talking and its e-learning module, it was important that it would move and act consistently. In other words: there are many possible configurations of movement actions but these actions should not seem peculiar or unnatural. Many users reported that they enjoyed the robot's movements, and even waited for it to express its emotions, and if this did not occur, they were disappointed.

Table 14 gives the Likert scale elements related to the two questions A) the instructions to donate were clear and B) the learning material had an impact on the chosen target.

Table 14. The grouped Likert's scales values

Test Cases	**Median Value (Mdn)**		**I-Quartile Value (IQR)**	
	A	**B**	**A**	**B**
TC1	5	3	0	3
TC3	5	2	0	1
TC4	4	4	0	3
TC5	5	4	1	2
TC6	4	4	1	2

Users generally had a clear perception of good functionality of the Robo-eLC and the inter-quartile data from the Likert scale element shows that there was a strong consensus on such opinions. The users' assessment on the impact of the learning material on the chosen donation targets was somehow polarised showing that they had their own opinions (the inter-quartiles are significantly bigger). These data show that users benefitted from the HRI and that they received some learning support in a varied personal manner (the big inter-quartile figures for the second question).

The tailoring of the Robo-eLC e-learning modules (Sections 2.1 and 4.3) was not intended (at least primarily) to convince users to give their money but to allow them to acquire more understanding about fundraising issues and gain insight into how their money could influence the future in the Robo-eLC presented target fundraising goals. It seems that in this respect the robot (and also the InfoKiosk) can succeed in providing fitting learning material and "distributing" users' behaviours in choosing in a variegate way.

5.4 Users' information and feedback data in figures

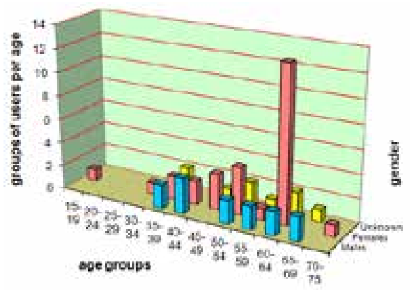
Some quantitative information related to the users' feedback (UF) of the Robo-eLC (Test Cases 1, 3 and 4) and the InfoKiosk (Test Cases 5 and 6) are presented in Table 15 (users' age distribution), Table 16 (functionality and efficiency of the Robo-eLC and InfoKiosk as fundraising systems) and Table 17 (impact and influence of the Robo-eLC and InfoKiosk on the donation process).

This quantitative data is based on the users' feedback forms (UF). The UF amounted to 50 in TC1, 4 in TC3, 9 in TC4, 16 in TC5 and 23 in TC6. The poor availability of quantitative data in some Test Cases was compensated for by the collected qualitative data (see the second part of Section 3.2.5).

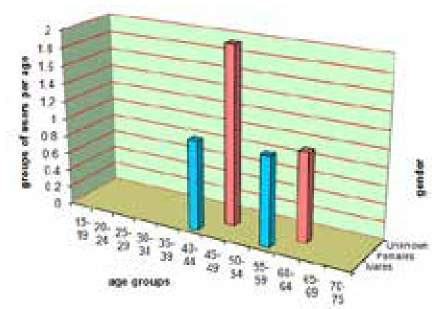
More information about the quantitative and qualitative data and how it was collected can be found in Sections 3.2.4 and 3.2.5.

Table 15. Age distribution of users

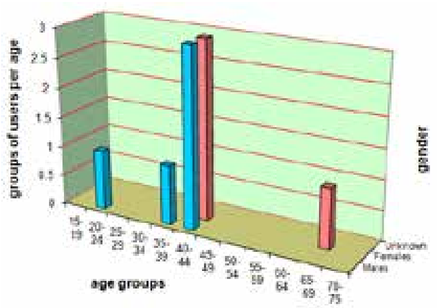
TC1 (Robo-eLC)



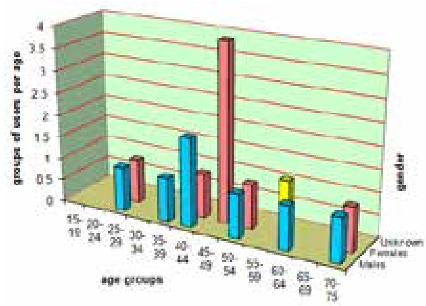
TC3 (Robo-eLC)



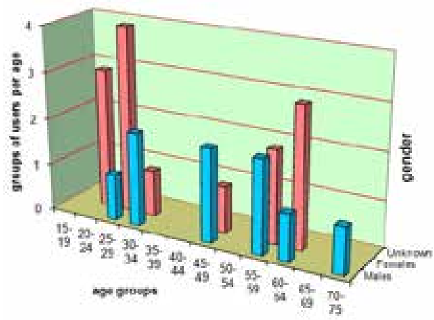
TC4 (Robo-eLC)



TC5 (InfoKiosk)



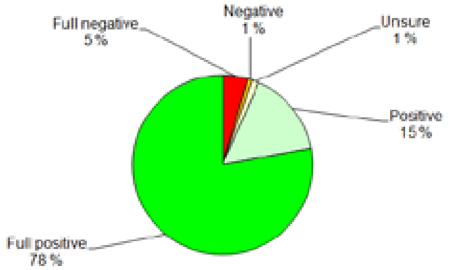
TC6 (InfoKiosk)



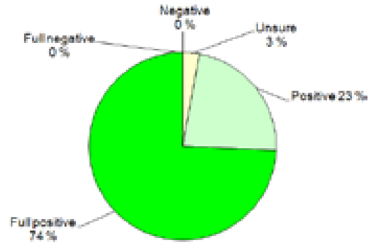
The available data show that users' age distribution varied according to the Test Cases. The qualitative collected data show that amongst the influencing factors were the events' organisational (i.e. time of the year, the event occasion, local event organisers purposes and strategies etc.) and environmental (i.e. location of the fundraising system and the location social value) factors. It is important to notice that there was some balance as far as users' gender and age distribution, which generally spanned the whole of adulthood, were concerned.

Table 16. Overall opinions regarding the functionality of the fundraising systems

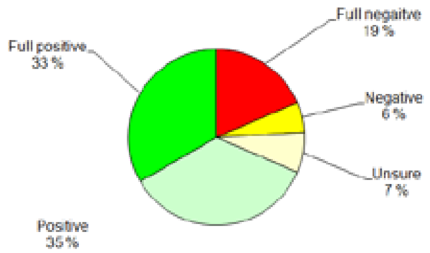
TC1 (Robo-eLC)



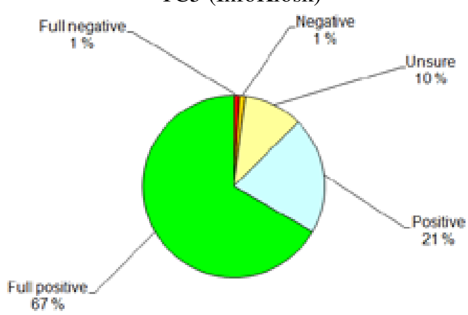
TC3 (Robo-eLC)



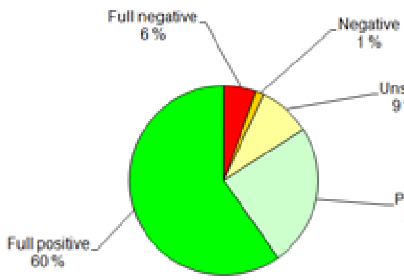
TC4 (Robo-eLC)



TC5 (InfoKiosk)



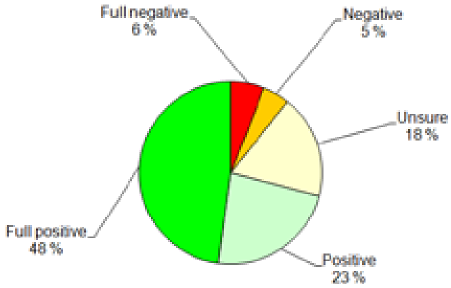
TC6 (InfoKiosk)



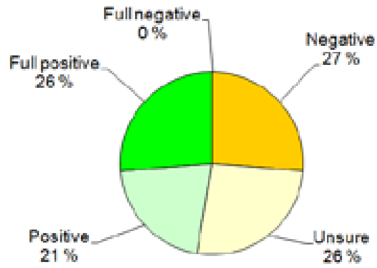
The UF provides information regarding the attributed efficiency and functionality of the fundraising systems (Robo-eLC in TC1, TC3 and TC4; InfoKiosk in TC5 and TC6). The graph above depicting TC4 (the Robo-eLC in the Noljakka's Chruch), in comparison to other events' graphics, indicates that the users of the robotic fundraising system displayed a higher negative attitude. The InfoKiosk (TC5 and TC6) used in the same environment and similar occasions, performed much better. The UBF and event observations corroborated this variation in users' behavioural attitude.

Table 17. Users' opinions regarding the impact of the fundraising systems

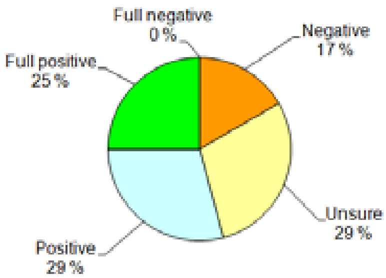
TC1 (Robo-eLC)



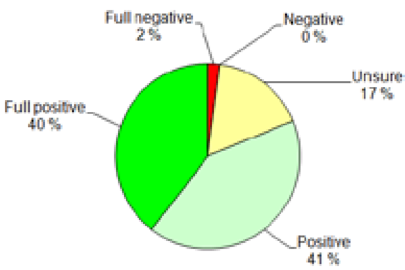
TC3 (Robo-eLC)



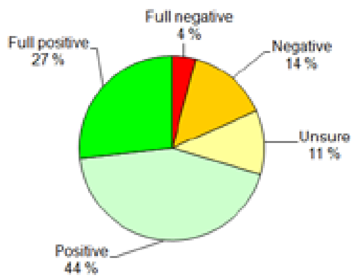
TC4 (Robo-eLC)



TC5 (InfoKiosk)



TC6 (InfoKiosk)



Users expressed their opinions regarding the relevancy of the fundraising systems (the Robo-eLC and InfoKiosk) and their role in the process of making a motivated donation. Attributing a low performance to the Robo-eLC in TC4 is in line with the general passersby's rejection of a robotic presence in a "humans only" environment. The TC5 graph above refers to the Christmas period and the TC6 graph to the post-Christmas period. Users' acknowledgment that the InfoKiosk fundraising system played a positive role in the interaction is visually evident.

5.5 Design roles of cognitive, affective and psycomotive domains for Robo-eLC

The evaluation analysis of the test cases' data have highlighted the role that cognitive, affective and psycomotive domains have in the design of the Robo-eLC anthropomorphic robot. In many events, the semi-structured interviews and other forms of user feedback added specific insight to the quantitative data, in particular on the occasion of unexpected robotic failure (in HRI efficiency or as a fundraising means). The outcome results of Test Cases 5 and 6, with the use of the InfoKiosk, provided information that remarked or confirmed some hypothesis developed in the previous robotic test cases.

The cognitive domain has a relevant role (that *must* be satisfied) in the design of the e-learning modularity and multimodal interface of the robot. Users attach a high value to the intelligence of the robot's interaction and the information that it provides to stimulate the learning process in the donation interaction. The user's ego needs to be supported and motivated in the process of exploring, understanding and learning to acquire and adapt to positive behaviour. This process should happen in an intuitive and reflective way, affording users the opportunity to discover, without a perception of being imposed upon or forced. All of this requires proficient design skills, not only for the GUI but also for the physical and aural elements of the robot (PAPER VI). The Robo-eLC's behaviours must be synchronised, based on users' expectation, even those that are not explicitly uttered (a user centred analysis and design is required). The InfoKiosk test cases confirmed that cognition is stimulated by the positive learning environmental conditions (which open the way to mental gratification in the achievement of each learning fact) and they also proved that human preconceptions (cultural and educative) can jeopardise the perceived efficiency and functionality of the Robo-eLC. A mental lock and refusal of robotic interaction can occur in such cases.

The affective domain is known to potentially boost and support the cognitive domain in human learning behaviours, this is also the case with the Robo-eLC HRI. The interaction between these two domains is fundamental to any long lasting learning strategy with the Robo-eLC. The possibility for users to attach values and emotions to the Robo-eLC was relevant in starting an interaction. This affective aspect is exercised by the Robo-eLC when it is easily recognisable and identifiable with a known cultural or social role in an acceptable usage environment. This is the Totem Phenomenon (PAPER II). There are also elements of the cognitive process (Kolb, 1984) that stimulate the affective elements throughout the individual and personalised learning process in experimenting. For better results (i.e. the individual's learning and the donation process) the HRI in the Robo-eLC must give users the opportunity to attach emotions to the process itself. This happens when the information supplied by the robot (e-learning modules and robotic activity) is actual and can affect a real impact dimension. Users attach emotions to their learning experiences. These emotions are evoked when they discover the real facts and opportunities for their potential fundraising support and feel at ease to accept the role of donor. The cases when users had a negative and/or unpleasant reaction (as observed and reported in users' behaviours in Test Cases 2 and 4) were mainly due to environmental circumstances (i.e. the suitability of the location of the Robo-eLC) and users' negative preconceptions regarding the presence of the Robo-eLC. The negative effects that people attached to Robo-eLC in Test Case 4 were removed by replacing it with the RoboAvatar system (Test Cases 5 and 6) which allowed people to accept and conduct a fruitful personal e-learning interaction.

The psycomotive domain covers an important role in the design of the Robo-eLC's movements which influence people's behaviour (users or passersby). Both quantitative and qualitative data analysis remarked how the movements of the Robo-eLC had a strong impact on people's perception of it as being alive. People waited for this peculiarity to appear and considered it a stimuli signalling intelligent interaction. Lack of movements, or desynchronisation, lead to people regarding the Robo-eLC as *machine-like* while the proper functioning of the robot added the value of *human-like*. People's perception of the congruent robot movements raised their cognitive behaviour which, in turn, influenced their learning attitude. Part of the failure of the Robo-eLC in the church premises (Test Case 4) can be ascribed to it being perceived as alive (and soul-less) which contrasted with attendees' cultural and educative background. When viewed in terms of perspective, the psycomotive element developed by the robot was too effective.

6 Conclusions

This thesis work highlights the ways in which the robot Robo-eLC can be an effective fundraising mean (an electronic successor to the traditional Finnish Vaivaisukko) and a tool for teaching e-learning behaviour to people entering into interactions with it. The robot was capable of initiating a HRI (pleading for users' attention) and supporting users' interactivity. E-learning modules were designed and integrated in the robot and a tailored GUI, for iconic intuitive use, was developed. A modular navigation touch navigation system was devised to be used via the robot's touch screen and a simple but secure donation module was also integrated. The Robo-eLC has been analysed and evaluated according to its impact as a cognitive, affective and psycomotive partner in HRI. For a better understanding of some study results on its performances in Test Cases 2 and 4, a multimodal pillar kiosk (the InfoKiosk) was developed to gain triangulation evaluation data.

The Robo-eLC expressed presence, embodiment and identity in reaction to which users were generally prone to start a learning interaction. The iconic representations of facts and figures of fundraising issues and the informative data in the e-learning modules worked together with the interactivity of the robot to create suitably interactive situations. People expressed, on many occasions, affective behaviours which correlated to their cognitive behaviours. In addition, the psycomotive element was a relevant factor in the HRI stimuli.

Some of the results seen in this work, partially agree with Mori's (2012) considerations of the Eerie Valley (also known as "The Uncanny Valley") regarding human refusal of an anthropomorphic robot which looks too human but Test Cases 4, 5 and 6 show that this is true only when the cultural and educative circumstances set a psychological rejection. Nevertheless, as supported by Groom et al. (2009), I obtained strong results in this work that show how people are in favour of having an anthropomorphic robot (i.e. the Robo-eLC) as an interactive partner in HRI for fundraising and e-learning purposes. This is also supported by MacDorman et al. (2013) who comment on the tendency of people to ascribe positive human qualities to anthropomorphic robots that act like humans. In addition, Dirkx (2001) underlines that learning is fundamentally grounded on emotions and these, in turn, are dependent on the particular socio-cultural and psychic context in which they emerge.

The three-folded research approach adopted in this thesis shows convergent elements to support the general concept of Arkin et al. (2003) that for enjoyable and lasting interactions with robots, an understanding of human psychology is required. This thesis' results concerning the role of the affective domain in HRI for the Robo-eLC, is in line with O'Regan (2003) according to whom positive emotions play a relevant role in teaching/learning. As in this thesis' three-folded approach, Picard et al. (2004) directly link the value of affect to the cognitive process and stress how learning technologies should benefit from multiple perspectives. Aspects of the psycomotive impact of the Robo-eLC on users, were in line with Rousseau et al. (2013) who highlighted that arm gestures and mobility in an anthropomorphic robot increases users' interactivity as long as it is not perceived as a threat. Arkin and Brooks (2007) also point at the importance of non-verbal communication between humans and humanoid robots.

I did not find clear respondent elements to Fink (2012) according to whom anthropomorphic features or behaviours which are too human might raise users' expectations that the Robo-eLC cannot fulfil. The reason might be that the Robo-eLC was not close to being too humanoid, despite the fact that it was perceived as such. Finally, I found respondent results with DiSalvo et al. (2002) in that the Robo-eLC is capable of projecting an amount of humanness and the users felt comfortable in the HRI.

My recommendations for future R&D in fundraising humanoid robots (but also in other sectors of anthropomorphic robots) is that researchers should adopt a three-folded approach for analysis and evaluation of works. This cognitive, affective and psycomotive study/impact approach will avoid missing some important aspects in the user centred design perspective.

Beyond the Robo-eLC my research interests are alternative fundraising interactive systems, human behaviour in HCI and HRI with a focus on interacting GUI.

The Robo-eLC is still "alive" inside my computer. The possibility to develop a dynamic intelligent mind in the robot is attractive and awaits support and opportunity to bring it back to life.

I borrow the words of Kusuda (2002) to close this thesis with:

"*Humanoid robots cannot be the sole goal of robotics. It will be a necessary result of future robot technology where affinity to human beings is an absolute MUST.*"

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Original Publications

Publications PAPER I

1

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Learning paradigms through fundraising systems: The RoboBeggar and the InfoKiosk cases

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1. Introduction

It has become common practice for many organisations that need to raise funds for humanitarian aide and charity to utilise electronic fundraising systems to reach potential donors. These fundraising systems can be classified into those that are Internet-based (i.e. virtual and/or informative online systems) and those that are hardware with embedded operating systems (i.e. robots or Automatic Teller Machines (ATMs), with or without multimedia integrated systems). While the designers of fundraising systems are mostly concerned with the actual process of raising funds by these means, they tend to pay less (if any) attention to the impact that the learning behaviours and ethical convictions of donors support conscious and motivated donation. The fact that designers seldom take the value and function of user-centred designs and the dynamics of elearning into account in the fundraising system that they devise, stimulated the authors of this paper to explore a range of pertinent questions in the field of hardware embedded systems in educational technology. They have asked these questions in order to identify the interactive paradigms and rules that govern the effective design of elearning fundraising technology. The authors are all experienced in the application of elearning to human-machine interactions for the purpose of identifying those elements that best support the cognitive and learning processes of novice ICT users.

This chapter offers an analysis of the results that were obtained from four research projects that investigated two prototype computer embedded systems: the RoboBeggar (La Russa et al., 2005), a gynoid robot, and the avatar-assisted InfoKiosk (La Russa et al., 2008), a multimedia pillar kiosk (see Figure 1 below for a photograph of the two prototypes). The anthropomorphic robot and the pillar kiosk were analysed and assessed in terms of how efficiently they performed their tasks of interacting with human donors and potential donors, and the extent to which they were able to influence human behaviour in their favour. Both of these systems used elearning modules that allowed people who had decided that they wish to make a donation, to make direct money transfers to the charity concerned by simply using their bankcards. This chapter compares the elearning methods of the two systems with the cognitive and learning processes of those who used the systems to make donations. This chapter also examines and analyzes the objective and subjective data (including user feedback) that the researchers collected from all the test cases.

Fig. 1. The RoboBeggar (left) and the InfoKiosk (right) – terminals of the two fundraising systems used for automated computer-based fundraising discussed in this paper

The efficacy of the fundraising systems that form the basis of the human-machine interactions are then assessed by the researchers on the basis of the data thus analyzed. A set of design guidelines has been specified in this chapter for the use of software programmers and engineers, anthropomorphic robot developers and fundraising organizations in order to serve as a basis for the design and development of effective elearning interactive fundraising systems (anthropomorphic robots or simple computer-embedded systems). The design of robotic or computer embedded elearning fundraising systems' programs can benefit from a structured and methodical approach that takes into account the design flexibility that is provided by these two presented prototype cases. Because the researchers adopted a Object Oriented Design (OOD) and Object Oriented Programming (OOP) to approach these problems, it was possible for them to redefine both of the two systems' program modules on the basis of user feedback and the interactions that took place between users and the hardware (related metadata was also provided by each system's software). The adaptability and flexibility of the programs that constituted the operational base for these two systems enabled the researchers quickly to incorporate the data that emerged from the learning processes of frequent users, thus enabling them to refine the systems until they operated with maximum efficiency.

By using newly emergent data, it quickly became evident to the researchers that donors clearly preferred to use and interact with the InfoKiosk in church environments rather than the RoboBeggar. This was vitally important information because it was already known that the RoboBeggar was the more noticeable and visible instrument for donation collection in other (non-church) environments. It might therefore have been logical to suppose that the RoboBeggar would also attract more attention and donations in ecclesiastical environments. But, for some reason, the opposite was true. This chapter presents and discusses the reasons and motivations for the positive and negative impacts made by different systems in different environments. The conclusions that were drawn from this data served as a basis for constructing a set of design guidelines for the designers of interactive elearning fundraising systems.

2. Fundraising in the third sector

During the past few decades, marketing and communication specialists have paid an increasing amount of attention to the possibilities inherent in fundraising by means of the systems mentioned above. At the heart of this activity have been attempts to define reliable criteria for soliciting strategies (Hart et al., 2005; Patterson & Radtke, 2009). During this same period, a large number of field studies and reports have been sponsored by fundraising organisations and other interested parties in the hope of identifying the conditions that promote or hinder fundraising activities, as well as related trends, needs and sector investments, and the expectations and expenditures that define this field of research (RNID a, 2008).

The amounts that are collected by fundraising organisations vary for each country. According The Charity Commission of England (Facts & Figures, 2009), the annual growth rate in fundraising between September 2008 and March 2009 was 6.8%, and although this figure has been showing a tendency to decrease, it is still in keeping with the total amount of money (UK£ 49.943 billion) collected throughout the world by 168,500 charitable and humanitarian organisations by 31 March 2009 (the cut-off date for this data). According to *Giving USA* (Bond, 2009), donations in the United States in 2008 reached a total of US$ 307.65 billion (a drop of 2% from the total amount collected in the previous year). The use of mobile phones for fundraising (which is called *mobile fundraising*) in the United States has also started to produce good results, with the total amount of about $500,000 thus. Although this figure is still far lower than the amount collected by more traditional methods of donation solicitation, it nevertheless represents 0.0016% of the total amount that was donated as a result of formal fundraising activities in the United States in 2007 and 2008 (Hiley, 2009). In order to obtain an accurate understanding of how vast the amounts are that are accumulated in the United States as a result of fundraising activities, it is enough to mention that the amount collected as a direct result of fundraising activities collectively constituted 2.3% of the Gross Domestic Product (GDP) in 2007, and is expected to represent 2.2% of the GDP in 2008 (Bond, 2009). Because it is possible to raise large amounts of money by means of fundraising, many organisations organise fundraising training courses to teach and train personnel in this activity (Murray, 2009). This is still happening in spite of an

increase in recent years in the number of management problems experienced by fundraising organisations with regard to their reserves policies and the degree of transparency with which they operate (Ainsworth, 2008).
It is worth noting that the use of "cold" door-to-door fundraising techniques is still widely used by many organisations, and, according to the Public Fundraising Regulatory Association (PFRA), this method of fundraising can still produce excellent results (Lake a, 2009; Lake b, 2008; Jordan, 2009). Ironically, it is the continued use of this traditional door-to-door technique (which is regarded as a tried-and-tested method that delivers good results) that accounts for the less-than-expected amount of interest in Internet fundraising methods, and various other online and offline techniques (Lake c, 2009).

2.1 The needs of the fundraising sector: money – but not only money

The needs of the fundraising sector cannot be comprehended only in terms of the ultimate purposes of the fundraising or the means that are used to pursue fund solicitation. The very nature of the fundraising organisations themselves and the degree of efficiency with which they operate, are also matters of great concern to these organisations. Most fundraising and non-profit organisations tend to use their own resources and expertise to reach potential donors, and they base their strategies mainly on their own past successes and failures. Because past successes dictate future methods for most fundraisers, they tend to keep approaching the same donors and to stick to the same methods of soliciting – thereby forfeiting whatever opportunities for improvements, expansion and increased efficiency that are currently offered by more advanced technological systems (Hart et al., 2005) and the advice of experts in this field (Patterson & Radtke, 2009). Studies have even shown that some organisations forfeit the advantages that could accrue to them from the publication of budgets and annual reports. Such reports and information are valuable because they increase transparency and trustworthiness by providing certified information about operations and plans for future strategy planning (Ainsworth, 2008).
While it is impossible to quantify exactly the total amount of money that is needed by non-profit organisations that intervene in critical situations and ameliorate a variety of urgent problems in the fields of health, social services, culture, law, politics, humanitarian aid, philanthropy, religion and the environment (Simon, 1995), it is nevertheless possible to define how much capital has been expended and to what extent the annual amounts that had been raised have diminished from year to year (see Bond, 2009). Reductions in amounts raised from year to year place an enormous strain on non-profit organisations and make it very difficult for them to maintain the quality and scope of their operations from one year to the next with fewer resources. It is interesting to note that annual reductions in the amount of money collected through fundraising affect mainly the e-fundraising sector (electronic fundraising that is based on Internet services or mobile systems). These (electronic) forms of fundraising have suffered far more from reductions in expected targets during the last two years than have traditional face-to-face (or door-to-door) fundraising methods. It has been hypothesized that face-to-face fundraising methods have been far more effective in raising more funds for their organisations because of their consistent investment in the training and preparation of volunteer fundraisers (Jordan, 2009).
In 2003, the United Nations (UN a, 2003) published guidelines that recommended certain standards and norms for the development and publication of data emanating from non-profit organisations. This report includes recommendations about the necessity for detailed

data about non-profit organisations, their activities and how volunteer activity should be divided to reflect national components. Although the data in this handbook is over a decade old, it nevertheless offers essential insights into the way in which voluntary work should be organised. In the years between 1995 and 1997 in Finland, the percentage of the population that made voluntary donations was 33%. The average for the European Union was 32%, and the average for the United States of America was 49% of the population (UN b, 2003).

Experts and analysts in this field agree that non-profit organisations have been aggressively positioning themselves in commercial settings (Weisbrod, 2000) because the benefits that might accrue to them from doing this have not escaped their notice. The advantages of being present and active in commercial environments and the benefits that can accrue to fundraising organisations from transforming themselves from non-profit organisations into profit-making organisations that function in competition with traditional businesses and shops, have now been widely accepted (ThirdSector, 2009). It remains to be seen whether fundraising will continue to remain at the high levels achieved in previous years by non-profit organisations once they become thoroughly commercialised and so possibly less deserving of support in the eyes of their established donors.

The administrative costs and the costs of promoting and expanding fundraising activities can exert a decisive effect on the organisational structure of fundraising organisations. The running costs of very large non-profit organisations in the United Kingdom vary from between 23% and 25% of their total income (Unicef UK, 2009; RNID b, 2008), while the equivalent amount for similar fundraising organisations in the United States is about 18% (Bradley et al., 2003). According to Bradley et al., the administrative and running costs of fundraising organisations could be reduced by 5-10%, with an equivalence in total savings for all such organisations of up to $100bn. The debate on how to effect savings is certainly not yet over. There is, for example, ample scope for internal structural reforms to their systems that many organisations could carry out without any outside assistance, that would substantially reduce costs and increase efficiency.

Finally, according the report entitled *Toward a New Asian Development Bank in a New Asia* from the Asian Development Bank (Panitchpakdi et al., 2007), 90% percent of the population in countries that are now reasonably stable will experience widespread *severe* poverty by 2020. This report is a warning to donors to prepare themselves for the advent of these conditions. The United Nations report entitled *The Millennium Development Goals Report 2008* (UN, 2008) emphasises that the fight against poverty in developing countries will require not only political will and determination but also *adequate funding* in the long run. While this United Nations report emphasises that both private and non-governmental organisations play a crucial role in a campaign against poverty, it also recognises that the actual amounts currently being collected are still inadequate for the purposes for which they are needed.

The revenue collected by fundraising organisations has to be adequate to finance the following activities, processes and assets:

1) Logistics
2) Administration
3) Technology
4) Personnel training
5) Budgeting
6) Investment goals

Our interests for the purposes of this paper and for future research are centred mainly on **technology** (the need to devise and develop additional forms of fundraising technology that will empower the work of fundraisers) and **investment goals** (the need to support current modes of fundraising by integrating them with various tried-and-tested procedures of elearning).

2.2 The need for fundraising: Some global reference figures

According the United Nations publication entitled *The Millennium Development Goals Report 2008* (UN c, 2008), there were last year (2008) a total number of 42 million displaced people throughout the world whose lives had been disrupted by various kinds of conflict and persecution. The United Nations itself was active in caring for 16 million of these refugees. When one examines what this publication as to say about the employment rates from various regions of the world, the following figures emerge: in the developing regions of North Africa, Western Asia and Southern Asia, the employed female population stands at only 22%, 25% and 34% respectively, as against the male employment rate of 70% (for the countries of North Africa and Western Asia), and 78% (for the countries of Southern Asia). These figures make it clear that the employment ratio of females in these regions is, on average, over 40 points lower than that of men in the same countries, while there is, on average, a difference of 20 points between male and female employment rates if one combines the figures for the remaining developing regions. The report notes that the creation of works that are specifically reserved for women and that are supported by local existing institutions would increase the employment rate of women and that this would enable these women to meet their family responsibilities more effectively than they do at present.

One in five of the workers from developing countries currently lives in extreme poverty because of low salaries and because about half of the jobs they have are temporary, ad hoc, transitory, frequently exploitative, and without guarantees or state regulation of any kind. When one analyses what the report has to say about nutrition, one notices that the number of undernourished children under the age of five has dropped from 33% (in 1990) to 26% (in 2006). This figure of 26% corresponds to over 140 million children (UN c, 2008).

Education in developing countries is also affected by poverty. The United Nations report mentioned above (UN c, 2008) shows that only 65% of children from the poorest strata in society in the countries surveyed had ever attended primary school as opposed to 88% of those from the richest strata of the populations concerned. In addition, a total of 84% of children in urban areas attended a primary school while only 74% attended such a school in rural areas. Even in refugee camps, only 6 out of 10 children are enrolled for primary education. In developed countries in 2006, primary school enrolment rates for girls was equal to that for boys (namely, 100% for both genders), while in developing countries the rate was 94 for each 100 boys who were enrolled (UN c, 2008).

While the mortality rate for children under five was 0.6% in developed countries, it was 8% in developing countries (UN c, 2008). Of the 500,000 women who died in 2005 (UN c, 2008), childbirth or in the six weeks following delivery, 95% of these deaths occurred in developing countries. While the number of women who die from complications incurred during pregnancy in developed countries is 1 out of every 7,300, the equivalent fatality rate in the sub-Saharan region (the developing region with the most fatalities during pregnancy and delivery), is 1 out of every 22 women. But what is of greatest concern for those who campaign for the treatment of HIV/AIDS patients, the proportion of population in developing countries who needed HIV retroviral therapy in 2007 was 31% while the equivalent figure was 22% in 2006 (UN c, 2008). These figures speak for themselves.

2.3 Learning in fundraising

The data and information provided by fundraising organisations together with available reports and reviews of their activities, indicate that such organisations are becoming more and more aware of the importance of motivating donors so that they will be willing to at least maintain the level of their past donations, even in the unfavourable economic climate that is currently afflicting the world. On the one hand, it is necessary for organisations to focus on the public perception of the charitable or humanitarian work that they undertake as well as on their status as reliable and trustworthy organisations, so that they will be in a strong position to continue soliciting funds from donors (Simon, 1995). On the other hand, it is vital to reinforce the perception of donors that it is their contributions that enable the recipient organisations to continue with the implementation of their humanitarian activities. It is this perception on the part of donors that motivates them to continue making donations from one year to the next (Huang et al., 1995; Ajzen, 1991). The more donors can be made to feel that they are playing a vital part in the maintenance of the organisation to which they contribute and in the realisation of its goals, the more likely they will be to continue to support the organisation as long-term, stable donors. Research has indicated that if current donors are given informative, periodic information in a suitable format about the progress, achievements, hopes and intentions of the recipient organisations, they will be more likely to continue their support in the future (Ajzen, 2006). It is the purpose of this paper to point out that fundraising organisations can maximise their donations by using appropriate methods of solicitation if they implement those learning principles that have been proved to be effective in motivating people either to become donors or to continue making donations to those fundraising organisations that they have supported in the past.

Most fundraising organisations have well-established procedures for reinforcing favourable donor behaviour on the part of their benefactors or on the part of potential donors. These procedures vary according to whether donations are solicited on the Internet or as a result of personal, face-to-face solicitation activities. It has already been established that the potential for reinforcing favourable learning behaviour on the part of donors or potential donors is far more effective when the solicitation is made online. The reason for this is that information that is entered online can be processed for more quickly than information obtained from donors who are making donations as a result of a personal, face-to-face encounter.

2.3.1 Differences in motivational potential in online and face-to-face fundraising

Most of the major fundraising organisations that operate online (such as, for example, the RedCross, 2009; UNHCR, 2009; Unicef, 2009; GivingUS, 2009; UICC, 2009; MSF, 2009) seek to reinforce favourable donor attitudes by providing their donors with carefully selected descriptions, figures and statistics at summarise their achievements and their future goals and needs. In some cases (such as those in FELM, 2009 and Unicef CH, 2009), graphics and animated interfaces are utilised to reinforce the benevolent intentions of current donors and motivate potential donors to become permanent benefactors of the organisation. But even when the quality of information is as sophisticated as this, the organisations concerned are still not benefiting from the kind of immediate feedback on donor behaviour and preferences and the various modes of interactivity that have been shown to be extremely effective in motivating current and potential donor behaviour. In most cases in which donation data is collected and meticulously processed before it is passed on to current and potential donors, no (or minimal) emphasis is placed on determining and responding to the personal preferences and wishes of donors.

The proper utilisation of certain human factors is fundamental in effective face-to-face fundraising. In many cases, it would seem to be is more effective to invest in the training of skilled human donation solicitors rather than to rely on the undoubtedly positive effects of proven online learning strategies – while both of these methods produce far better results than the kind of traditional solicitation methods that rely on standardised brochures or regressed in people to commit themselves to future donations by means of their signatures on a pledge.

Research conducted by Lake (2008b) and Jordan (2009) has demonstrated that face-to-face solicitation of donations is more effective than solicitation by means of online approaches in times of economic recession such as that which currently holds the world in its grip. This has been attributed to the value that donors place on the human interactions that they experience, as well as on the greater availability of volunteers and the ability of human donors to adapt their approaches during the interactive process. It is evident that the "human touch" is highly effective in augmenting the provision of data and information that is offered to potential donors in pamphlets, brochures and other kinds of publicity material. It has been hypothesised that online systems are not less effective because of the computer illiteracy of potential donors or their inability to grasp the significance of the information that they receive, but because the absence of immediate human contact, interactivity and the warmth of face-to-face encounters diminishes the impact of the information that is offered by soliciting organisations. Even though most fundraising organisations have long been aware that they have not yet maximised the potential of their donors (i.e. the amounts that individual donors would be willing to contribute under different circumstances), they had no idea about what they should do to remedy the situation. There are a number of academic studies (such as those of Thorme & Root, 2002; Pritchett, 2002; Mondi et at., 2007) that demonstrate (1) how motivation is closely related to learning, and (2) how goals that are relevant to the interests and concerns of learners, improve the quality of learning behaviour.

3. Existing technologies that promote fundraising goals

Many countries support the fundraising efforts of non-profit organisations by making direct contributions to their budgets or by creating tax-related mechanisms for those who wish to donate funds to an organisation of their choice. In some countries, for example, individuals and corporations are encouraged to indicate their desire to support particular non-profit organisations. Their government then makes a *pro rata* donation from their tax to the organisations concerned. Apart from the well-known formats of face-to-face and mail-dependent solicitation systems (even though the latter have proved to be expensive, ineffectual, cost-inefficient and repellent to potential donors), more and more fundraisers are making use of a variety of e-fundraising methods. Existing e-fundraising methods (according to BlackBaud, 2009; Kipnis, 2009; Andresen & Mann, 2007) can be categorized (for the purposes of this study) into those that are:

1. media-based
2. Internet-based
3. sponsor-supported
4. telephone-based

In the section that follows, the technology utilised by each of these methods will be described in turn.

3.1 Descriptions of the technology utilised by each of the above-mentioned methods

3.1.1 Media-based technology

Medi- based technology uses mainly radio and television programmes or inserts. While the fundraising organisations themselves usually pay the cost of transmitting the programmes concerned, many radio and television channels offer a certain amount of free broadcasting time to approved organisations. The audio and audio-visual programmes and inserts (most of which are short commercials that appeal for donations with which to fund the activities of the group) are professionally designed and produced in order to make the best possible impact on potential donors. These appeals for donations have come to be known as *aid solicitations,* and they are inserted into particular kinds of programmes in order to achieve the greatest possible impact. Agencies of governments will also, in some countries, offer various kinds of assistance in order to achieve an optimal distribution of these solicitations. Occasionally, humanitarian organisations will utilise CDs or DVDs to get their message across to the public because these options are less expensive than straightforward advertisements that are inserted into scheduled programmes.

3.1.2 The Internet

Internet-based methods for soliciting donations tend to use the following three main methods of attracting voluntary workers and accumulating capital:

(1) They appeal for online donations.

(2) They offer online subscriptions that entitle respondents to membership of an organisation, a periodic newsletter and active support from the organisation for a specific length of time.

(3) They appeal for committed individuals who will be prepared to donate specific, regular amounts that will help the organisation to get its head above water in times of unforeseen need or crisis.

While many Internet-based systems are frequently simply a kind of electronic carbon-copy of what appears in the organisations' journals, they also are able to include far more data than can be contained in journals. The Internet-based format includes articles, fundraising figures, pictures and photographs, online videos, statistical graphical data that indicates the extent to which goals of the organisation are being achieved, and links to other relevant websites. They also offer secure access to donation pages and the opportunity to leave messages and comments. In some cases, organisations offer small gifts in exchange for donations. Donors thus receive small but useful gadgets or other desirable objects as an expression of thanks for their generosity. This exchange of symbolic gifts for donations has been found to be effective because it increases the sense of relationship that donors have with the organisation to which they have contributed.

3.1.3 Sponsor-supported methods

Sponsor-supported methods are usually embodied in the following two forms: (1) Hidden support methods. These methods are not necessarily hidden from view (although they can be at the discretion of the owner of the media or the sponsor of the provider). They are based on the calculation of a percentage of the commercial profits that devolve to the fundraising organisations involved. (2) Expressed support methods. In these cases, the commercial or legal entity aims at achieving a synergy between its own online products and the fundraising organisation concerned.

3.1.4 The *telephone based* soliciting.

Telephone-based soliciting has recently been opposed by a number of consumer organisations, and seems to be falling gradually out of favour. Telephone contact is nevertheless still used for making direct contact with potential and actual donors, and also for gently reminding established donors that their donations might be overdue. Telephone surveys are also used for investigating specific problems, and for attempting to gauge (by means of Gallup poll-type surveys) the kind of future support that an organisation might expect as they engage in strategic planning. According a recent survey (Harvey, 2009), telephone soliciting is the third-least cost efficient method for soliciting donations, ahead of the direct mail method and the use of newspaper advertisements.

3.2 How these forms of technology are used in fundraising campaigns

Large and well-established fundraising organisations (such as UNICEF and the Red Cross), that are already well known to the majority of the public, find it easier on the whole to use various forms of media technology and to benefit from their uses. Such organisations are supported by large numbers of established donors because the range of the operations is far wider than those of smaller, local organisations. But these smaller organisations can make effective use of local media and online programs to generate support for the causes.

While the Internet is widely used by all fundraising organisations in developed countries, the quality of their services and the methods that are used on websites do not vary much in proportion to the size of the soliciting organisation. All organisations – whether large or small – tend to approach their clients in the same way. Their websites offer online opportunities for donors to make contributions, to subscribe to membership of the organisation, and to recruit volunteers who are freely willing to serve the organisation in whatever capacities the organisation needs (Kipnis, 2009). Nowadays it is usually only small- and medium sized fundraising organisations that make use of the telephone for direct soliciting, and then only rarely. Because so many of these small- and medium-sized have been disappointed by the amount of money that they are able to raise by using technology- and Internet-based appeals, they are turning more and more to face-to-face methods of soliciting without actually closing down their online solicitations sites.

3.3 The failure to apply research findings to online learning processes

The methods that fundraisers use to condition their donors by applying what is known about human learning and conditioning processes are very similar to those used by non-fundraising organisations. The commercialisation of the media throughout the world has exerted a strong influence on the methods selected by non-profit-making organisations to achieve their aims. These organisations use tried-and-tested techniques on their websites to attract the attention and cooperation of potential donors by combining statistical data with images, text, video and other online methods. Unfortunately, however, they frequently fail to consider the *saturation* point (the point at which a generic user has absorbed the maximum amount of data that they can handle at any given time) and the *immunisation* point (the point at which users develop a strong resistance to the messages contained on the site). There is an ongoing discussion among academics about the way in which technological fundraising strategies could be changed for the better. Some feel that there is a strong need to reach people individually and to motivate them to enrol as future donors while at the same time inspiring established donors to continue making donations. Others feel that what is already known about advanced elearning techniques is not being adequately applied to the actual methods that are being used online to solicit donations.

4. Modern learning paradigms that are relevant to fundraising technologies

While most fundraising organisations use widely accepted methods for approaching and motivating donors, most tend to underestimate the communication possibilities inherent in certain modern forms of technology. The fact that many fundraising organisations have begun to operate as profit-making organisations that sell their products seems to have made them oblivious or one of the most important ethical imperatives for fundraising organisations, namely, educating their donors in the importance of the moral dimensions of charitable donation as well as the necessity for the services that they provide to those who cannot provide them for themselves. More attention is thus devoted to planning strategies to accumulate the funds that they need to maintain the organisation and its work at the expense of teaching their donors about the importance and value of giving to charitable and humanitarian causes as a moral activity that is valuable in itself. A typical scenario encountered by online users who access fundraising organisation websites is the following:

1. A main page that contains a number of links by means of which the user can access other categories of information.
2. An assemblage of a pictures, figures, videos and diagrams that explain how the most recent solicitation campaigns have fared together with extensive articles that are concerned with the issues that would be of interest to those who are most likely to become donors.
3. Site maps that direct a concerned user to explanatory information that describes the history and mission of the organisation as well as information about the past and present activities in which it has engaged.
4. Link(s) for accessing a secure donation page on which those who so desire can record their personal data and commit themselves to making various kinds of donations as well as offering whatever other voluntary services the organisation may need to further its aims.

It is evident that this kind of website structure and layout strongly resembles that of a well-organised book that is intended to provide students with the greatest amount of relevant information in the briefest possible format. The title page thus serves to introduce the reader to what he or she might expect in the book. The links on the website are equivalent to the table of contents that describe the chapters. The articles on the site are equivalent to the chapters of the book. The site map serves the same function as the index. Photographs, pictures and figures serve the same function in both formats. The secure donation page on the website is equivalent to a card inserted in the book, that solicits funds to cover production and distribution costs. Just as books that are unwieldy, unattractive and poorly organised are unlikely to attract readers, so a website that is poorly organised, confusing and unattractive will attract a few readers and even fewer donors. A table of contents that contains incomprehensible and poorly constructed chapter and section headings, will immediately alienate the average reader. Content that fails to stimulate interest will not motivate readers to further investigate what the book has to offer. Just as a reader who is intriguing by all the factors mentioned above will become more involved with the actual content and purpose of the book, so a reader who is antagonised by all the negative factors referred to above will quickly lose interest in whatever the book has to offer – however valuable it may be. The parallels between an effective book and a website that attracts and holds the attention of an online viewer, are helpful for understanding what it is that is required to make a fund-soliciting website effective.

Some organisations, such as those that partly or wholly use the informative graphic interface of FELM (2009) and Unicef CH (2009) are largely successful in educating donors in the value of their contributions for alleviating distress and furthering the work of humanitarian and charitable organisations. But such websites represent only a small fraction of those that are designed to motivate new donors and persuade established donors to maintain their support. The vast majority of fundraising organisations tend to rely on the conscience and compassion of potential and established donors to motivate them to give or to continue giving. In so doing, they place an inordinate emphasis on the kind of information that is contained in graphs, numbers and statistics – information that is mostly indecipherable and incomprehensible to the majority of non-specialist donors. This kind of approach is naïve and shortsighted and is bound to be ineffectual in the long term. Organisations that rely on such uninspiring, conventional and traditional methods of motivating donors will probably encounter great difficulty in increasing the amount of their donated capital and the number of their participant donors in the long run (Ajzen, 2006).

When we assess the value of modern learning paradigms in the fundraising sector, it is vitally important to emphasise the fact that technology will completely transform learning processes in the education industry within the next five years. Much progress has already been made in the transformation of education in highly developed countries, and, in the absence of catastrophic unforeseen circumstances, we will witness a period of exponential growth in the use of elearning as elearning as it replaces conventional "talking head" lecture-room teaching and learning in the education system (Glenn, 2008). For this reason alone, it is both naive and shortsighted to expect that there a similar transformation is unnecessary in the world of fundraising technologies. It is fact vitally important to the survival of fundraising organisations for those who design their methods and approaches to make full use of the proven successes of elearning methods in the academic world. If fundraisers incorporate the lessons pioneered by elearning experts into their fundraising approaches, they will be able, not only to educate their donors in the moral and ethical value of donation as a humanitarian activity, but will also be able to motivate established donors to remain on the donor list and to increase their donations as and when they can. Any failure to understand the way in which people have become accustomed to being approached in this electronic age is bound to undermine the financial health and the administrative viability of donor organisations in the years to come.

5. RoboBeggar and InfoKiosk: description and analysis

The architecture of the InfoKiosk software that was installed in the multimedia kiosk is a variation on the original software that was used for the gynoid RoboBeggar (see Figure 1 above for photographs of both the RoboBeggar and the InfoKiosk). An anthropomorphic avatar was integrated into the software of the InfoKiosk system by the creation of a frame distribution in the user interface (De Carlo, 2007). This enabled the necessary modularity changes and updates to the software elearning components, and these factors ensured that all the advantages of Java easy *object oriented programming* would be preserved. The software components that were removed from the InfoKiosk included the microcontroller of the motor (because the robotic hardware had already been removed), and the internal Internet browser software. While the RoboBeggar robot interacted with users by means of movements, verbal communications and touch-screen responses, the InfoKiosk interacted with users by means of a touch screen, verbal communications, and the actions and reactions of the avatar. The modules that were deactivated in the InfoKiosk were still present (though dormant) in the software and were thus ready for possible reactivation should it become necessary to construct a robot that required the RoboBeggar software or the hybrid version of the software in the InfoKiosk.
It is necessary at this point to say something about the Java program that is part of the two fundraising hardware systems. The software of both the RoboBeggar and the InfoKiosk fundraising systems connected the various modules which, in turn, interacted with one another by means of a message-passing mechanism. The main module of the system was the *kernel module*, which was responsible for the behaviour of the system because it regulated the function orders and commands. When the whole programme was loaded into the system, all of its components, as well as the configuration of the system, were stored in XML files. These included the sound responses, the repertoire of movements performed by the robot, and the different attitudes and responses that the avatar was able to convey to a user. The InfoKiosk software was finally reconfigured so that it could run from within any directory and maintain stable databases.

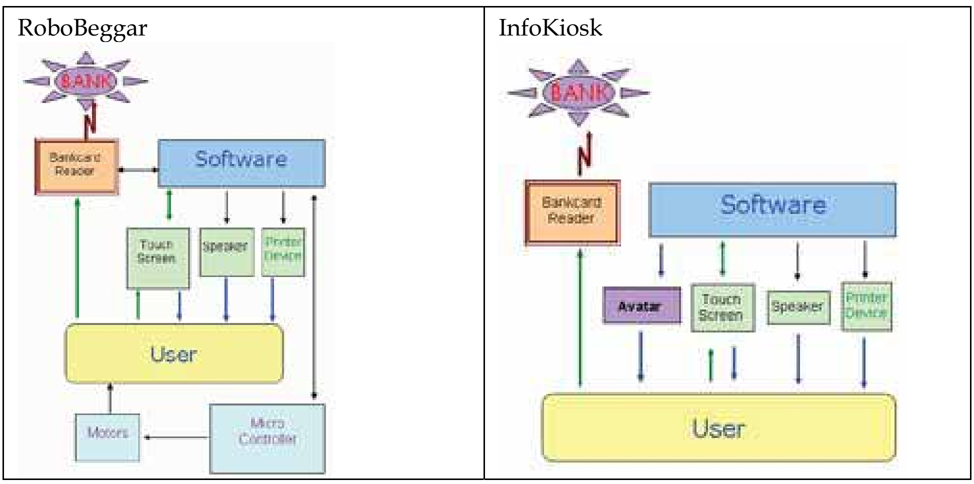


Fig. 2. The respective structures of the RoboBeggar (left) and the InfoKiosk (right)

5.1 RoboBeggar architecture

The RoboBeggar was an interactive automated robot designed for various fundraising purposes and elearning activities (La Russa et al., 2005). Elearning modules were integrated into the software so that possible donors might become sufficiently motivated and intrigued to make donations. The robot consisted of a complex combination of software and hardware devices that included:

- Software (to manage and control the whole system)
- A touch screen (so that users could enter their inputs into the software)
- Servomotors (to move the robot's head and limbs
- A microcontroller (to control the robot's movements)
- Speakers (for enunciating vocal communications to the users)
- A printer (to provide users with a receipt describing their completed bankcard operations)
- A bankcard reader (so that the users' accounts could be charged according to their instructions)

The servomotors controlled the movements of the head, the arm and the hand. The robot itself was able to move through 6 degrees of mobility (DOM). The software controlled the movements of the robot by means of a microcontroller that was connected to the system through a serial port (COM1). The robot could make a range of appropriate pre-recorded vocal responses about its purpose and donations through its loudspeakers. The touch screen presented a selection of data, pictures and information relevant to the fundraising targets to its users. Since the successive actions of users were tracked through their interactions with the touch screen, the software was able to count the amount of idle time and the time that passed between any two events initiated by a single user. The bankcard reader, which was provided with GSM transmission for the communication of data to banks by means of secure servers, was connected to the system through a serial port (COM2). The bankcard reader was therefore capable of reading the bankcards' magnetic tape and charging the required amount to the donor's bank account via the GSM connection. The printer, which was integrated with the bankcard reader but which was easily detachable so that it could operate through an external standard printer, provided the donor was a receipt after the money transaction had been completed.

5.2 InfoKiosk architecture

The InfoKiosk software was based on the core software that we had already used for the RoboBeggar because it was also designed to solicit donations for different purposes by using elearning modules and vocal communications (La Russa et al., 2008). The virtual avatar software was therefore adapted from the robotic program. This software was then installed into a multimedia pillar kiosk that was about 80 cm in diameter and 160 cm tall, and which was equipped with electronic components and multiple connectors (Figure 1).

Interactions with users occurred by means of a touch screen. During interactions with users, at the user interface always portrayed an image of the anthropomorphic avatar so that it could function as the "ego" or virtual personal identity of the InfoKiosk. The main purpose of the avatar was to encourage users to interact generously with the system by creating a friendly, amusing and interesting interface during the donation solicitation process and during that time that the donor passed through the various stages of the automated learning program. The successive phases of the interactions generated by the InfoKiosk were basically very similar to those used by the RoboBeggar because they both used similarly structured e-learning modules (screenshots with associated vocal messages and graphical information). Even though some users remembered the RoboBeggar from their previous interactions with it, none were able to recognize the similarities between the user-interface software employed by both systems. The microcontroller and the motors in the original architecture were rendered dormant even though they remained present in the code of the common software. Figure 2 presents a graphic representation of the architectural structure of the InfoKiosk. Figure 3 (below) are screenshots that capture the appearance of the avatar and the way in which it was presented to users.

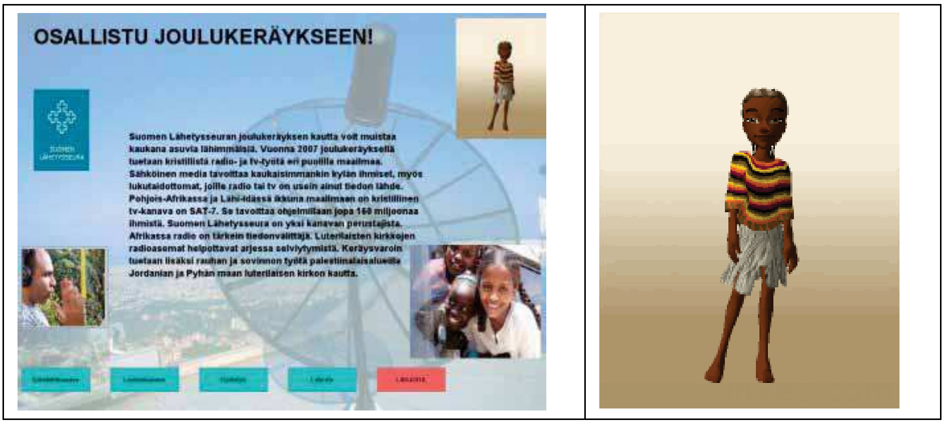


Fig. 3. A main window of the InfoKiosk user interface (left), and appearance of the avatar (right)

5.3 Analysis of the data from the test cases (trial runs)

Multiple Choice Questionnaire (MCQ) forms that were designed to provide the researchers with additional data for use in analysis and evaluation, were offered to people who approached the fundraising systems during their trial runs. The questionnaires were similar for both systems, and consisted of questions that provided information about:

(1) Gender
(2) Age group
(3) The functionality of the RoboBeggar/InfoKiosk (seven questions)
(4) The effectiveness and influence of the RoboBeggar/InfoKiosk (four questions)
(5) User evaluations and assessments (five questions)
(6) The donation system application (four questions)

A blank space was included in which users could write any additional messages they wished to send to the researchers and/or the designers of the RoboBeggar or InfoKiosk. A message in large bold letters at the bottom of the first page of the questionnaire requested users to record any additional personal observations, contributions or comments on the reverse side of the questionnaire form.

In order to avoid confusion or interpretative errors on the part of the researchers, users could respond in one of two possible ways according the type of question being asked (Uebersax, 2006):

(1) They could express their opinion in terms of the following scale:
1 = My opinion is completely different.
2 = My opinion is largely different.
3 = I cannot decide on an answer (I am unsure).
4 = My opinion is largely the same.
5 = My opinion is exactly the same.

(2) They could choose one of the following three options:
- No.
- I cannot decide (I am unsure).
- Yes.

The comparable data collected during the trial runs of the RoboBeggar and the InfoKiosk is represented in parallel diagrams in Table 1 (below). The data is presented by means of percentages of total answers obtained in response to specific questions or statements. The RoboBeggar and InfoKiosk trial runs were undertaken in Finland between 2003 and 2008. These trial runs or test cases were conducted at the following places and on the following occasions (La Russa et al., 2008):

1. *Large Non-Profit National Meeting Case*. June 2003. Thousands of people attended this meeting. Its purpose was to attend to various matters concerning the activities and business of a large non-profit national organisation.

2. *Bank Hall Case*. September 2003. The purpose of this meeting was to consider matters relating to fundraising campaigns in developing countries. We placed the RoboBeggar inside a bank hall through which hundreds of people were passing by.

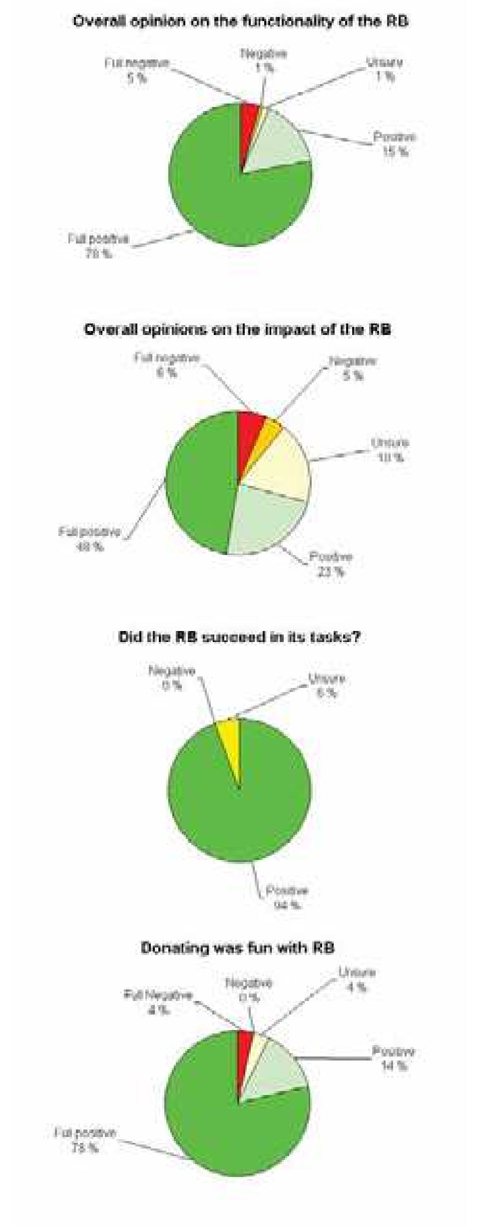
3. *Cancer Campaign Case*. February 2004. The purpose of this meeting was to consider matters relating to a fundraising support campaign on behalf of a national non-profit cancer-fighting organisation. We play the RoboBeggar in a mall where thousands of people passed by.

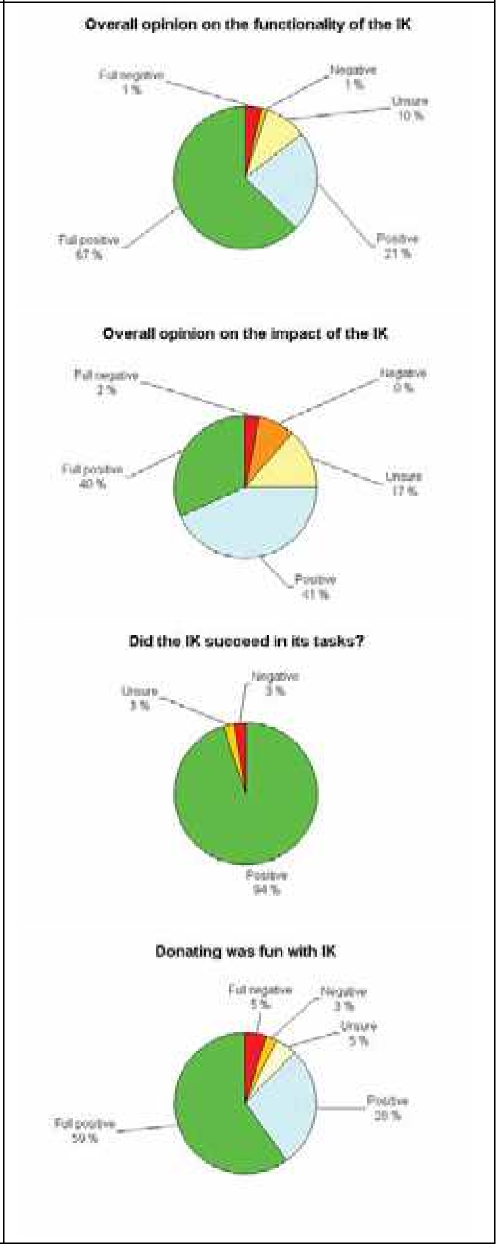
4. *Developing Countries Case*. December 2004. The purpose of this meeting was to launch a non-profit organisation to support various causes in developing countries. We placed the RoboBeggar in the entrance hall of a modern church which was attended by hundreds of people every week.

5. *Work With People Case*. December 2007 to January 2008. The purpose of this meeting was to support the campaigns of a non-profit organisation that was engaged in humanitarian work with people in developing countries. We placed the InfoKiosk in the entrance hall of the same modern church building that was used in the case of the *Developing Countries Case* (#4 above). Hundreds of people attended the meeting.

We analysed the data so that we could obtain a clear idea of how the two systems performed when faced with similar fundraising goals and similarities in objectives and achievements. The graphic below (left) presents data collected by the RoboBeggar during the *Large Non-Profit National Meeting Case* event that was made available for interaction with meeting participants throughout the whole course of the event. The graphic below (right) presents data collected by the InfoKiosk during the *Work With People Case* events that took place in a church that volunteered the use of its buildings for the occasion (La Russa et al., 2008). We took deliberate steps to ensure that the structure of the elearning modules remained structurally similar in both systems so that we would be in a position to make valid comparisons between the different sets of data at a later stage. In some cases, users took the opportunity to make a variety of personal comments and remarks. Even though some users remembered the RoboBeggar from previous interactions, they failed to recognize that the user-interface software that was used in both was in fact the same software. Additional data included data obtained from Focus Group interviews and observations of the behaviour of users as they interacted with the two systems.

Feedback from the RoboBeggar test cases	Feedback from the InfoKiosk test cases





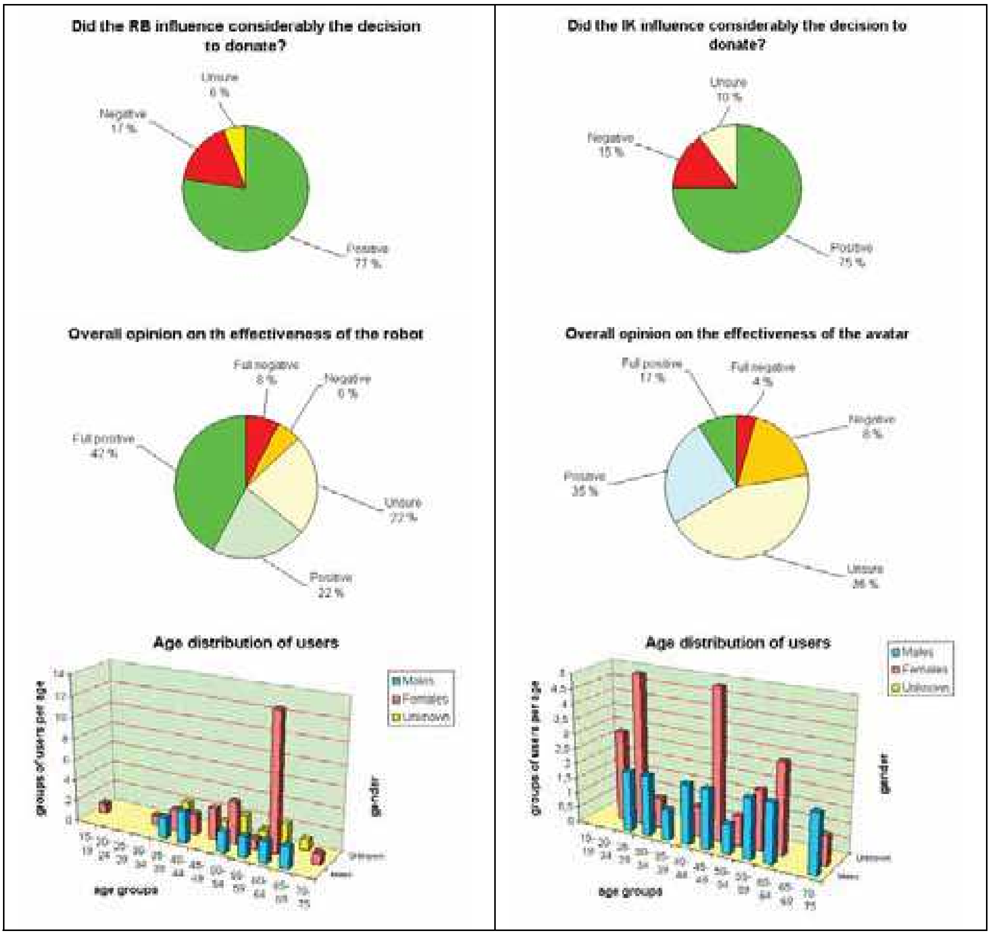
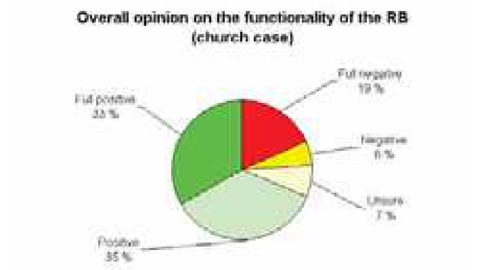
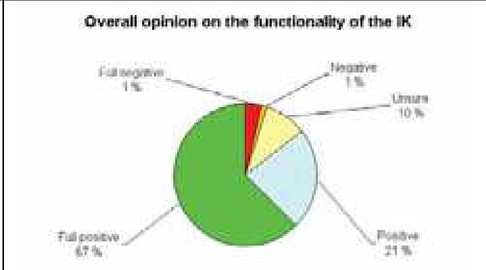


Table. 1. An analysis of the data that was obtained during interactions between the RoboBeggar and the InfoKiosk and their respective users

We set up the RoboBeggar and the InfoKiosk on the same premises (Figure 1 shows how they looked when they were on the same location) so that we would be in a position to detect differences in their performances under similar circumstances. Table 2 (below) sets out the most significant differences between the two systems from an analysis of the feedback data in adjacent columns (below).

<table>
<tr><th>Data relating to the RoboBeggar when it was set up in the same premises as the InfoKiosk</th><th>Data relating to the InfoKiosk when it was set up in the same premises as the RoboBeggar</th></tr>
<tr><td>


</td><td>


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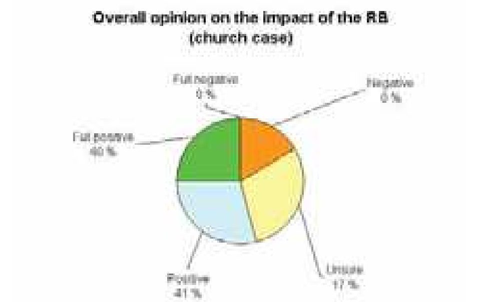

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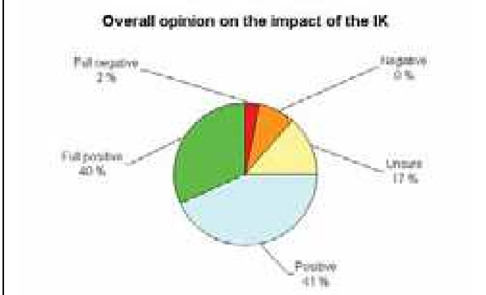

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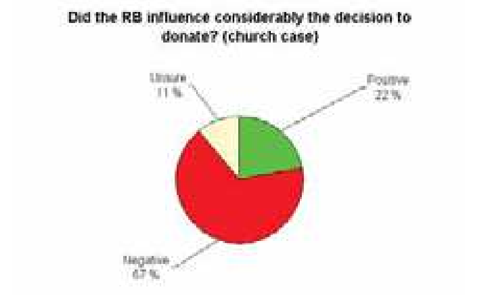

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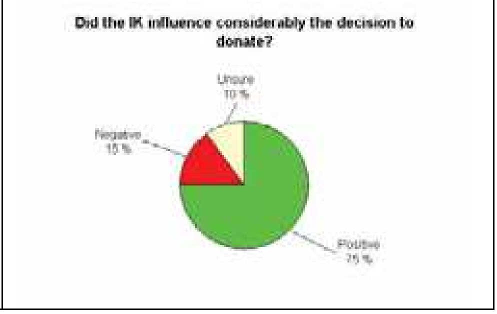

</td></tr>
</table>

Table 2. An analysis of comparative data when the RoboBeggar and InfoKiosk were set up in the same environment

The most striking differences were observed in the reactions of people to the two systems when the RoboBeggar and InfoKiosk were set up on the same church premises and when the RoboBeggar was set up in other (secular) environments. The cognitive reactions of the donors were for some reason more pronounced when they used the InfoKiosk on the church premises than when they used the RoboBeggar in the same location. The RoboBeggar performed well in other locations and during other events, it did not perform as well as the InfoKiosk under similar church circumstances.

All in all, these elearning-based fundraising machines proved to be both efficient and effective in soliciting donations if they were set up in appropriate environments. The InfoKiosk in the *Work With People Case* (in the church environment) outperformed the RoBobeggar in the *Developing Countries Case* (in the same church usage) because of its non-intrusive hardware (even though the two systems were utilising practically the same software structure and very similar elearning modules). The data shows that people reacted negatively toward the RoboBeggar because of its humanoid appearance. Our personal observations on these two test cases also confirmed that the humanoid appearance of the RoboBeggar made many people who approached it feel uneasy. The people who used the anthropomorphic robot were at the opinion that the anthropomorphic robot would be more appropriate for locations other than church premises. People felt reluctant to interact with the RoboBeggar on the church premises because of what they felt were the spiritual implications of *human beings* interacting with *humanoids*. The cultural and religious education of the members of this church (i.e. their conviction that a church should only be used by living people), made them feel acutely uneasy about permitting a robot that mimicked human behaviour to perform in a sacred environment. On the other hand, those who were brave enough to use the RoboBeggar for the donation purposes on the church premises evidently appreciated its performance, the service that it made available, and its learning features. But even these people retained a *negative attitude* toward the robot (as is evident from their feedback and comments). The people who attended the church somehow perceived the RoboBeggar as some kind of threat to the supremacy of *human* self-consciousness and uniqueness. The InfoKiosk, by contrast, was perceived as a neutral tool that in no way mimicked human behaviour or consciousness, and they therefore raised no objection to its presence and purposes – even though the software that activated both systems and the routines through which it took all donors were, for all practical purposes, identical. Not even the avatar-like features of the InfoKiosk seemed to bother them.

6. Discussion

Our observations of the behaviour of the people and users of the two systems confirmed that the InfoKiosk was regarded as less intrusive and somehow less threatening than the RoboBeggar. At the end of each of the seven church services after which users were given opportunities to interact with and utilise the InfoKiosk, no one showed any signs of repulsion or uneasiness in the presence of the InfoKiosk or any uneasiness with the way in which it worked. (The InfoKiosk, exactly like the RoboBeggar in the test case *Cancer Campaign Case*, called out to people to approach it and to begin to use the donation system that it contained.) We noticed that people moved around the entrance portal of the church without creating any empty space around the InfoKiosk, while, in the case of the RoboBeggar that was set up in the *Developing Countries Case*, people created an empty space with a radius of about 2-3 meters around it. The only exceptions to this were made by the children who, by contrast, used to approach the RoboBeggar joyfully and playfully out of simple curiosity. We also noted that, during some events, many people were clearly delighted and positively curious about the InfoKiosk – despite the fact that they were obviously in a hurry to leave the place.

The focus group interviews that were conducted with the cooperation of church pastors, deaconess, partners, local workers and event organizers, confirmed the live observations that we made in the *Developing Countries Case* and the *Work With People Case*, namely that people felt relaxed and in no way disturbed in the presence of the InfoKiosk (the only exception to this was that some workers collided a few times with the InfoKiosk because they were either distracted or because they had not yet become accustomed to its presence and location). Those who most enthusiastic about the InfoKiosk were the children. They asked numerous questions about the InfoKiosk and its functions, and the InfoKiosk screensaver (an animated rotating globe of the Earth) became occasions for learning and discussing some of the basic facts of geography). They also wanted to know how they could access the learning modules. This behaviour of children was similar toward the RoboBeggar during the *Developing Countries Case,* and they demonstrated a great deal of curiosity about the mechanical components of the robot.

Apart from the Multiple Choice Questionnaire, people returned some written comments during the trial runs in order to contribute to the systems' assessments and further design. Most of the comments concerned the use of bankcards (people were unsure about whether they could use a debit card in place of a credit card), and some were uncertain about how to operate the bankcard reader (they were uncertain about the direction in which they should swipe the card and how quickly or slowly they should do this in order to make contact with the machine). Some users complained about the fact that the text was too small for their visible acuity in the visual learning modules. In other cases, people made suggestions about how the instructions could be rephrased or corrected in the text of the learning modules. A few users asked for more donation options or access to similar non-profit fundraising organizations to which they wished to contribute. Similar comments were made in the focus groups. We were struck by the fact that people did not attach much importance to the presence of the avatar in the InfoKiosk, but that their attention was more absorbed by various aspects of the learning modules.

The fact that the systems were capable of talking back to donors and users constitutes a milestone in the design and production of machines that utilise human-machine interaction for fundraising purposes and behavioural studies. We fully expected that no one would try to talk directly back to the InfoKiosk, and no one did. But in the case of the RoboBeggar (La Russa & Faggiano, 2004), this happened quite often. While some people have expressed doubts about whether the avatar can help to realise donation targets or stimulate the donation process, an analysis of existing data shows that, in the current state of the art, there is no clear advantage in using avatars in integrated elearning fundraising systems. While the mean average donation for the RoboBeggar (in the *Large Non-Profit National Meeting Case*) was 12.6 €, the mean average donation obtained from the InfoKiosk (in the *Work With People Case*) was 10.9 €. In 2007, the local mean average donation obtained by non-profit organisations (for whom the *Large Non-Profit National Meeting Case* and *Work With People Case* were organised) by utilising the usual (conventional) channels and methods of fundraising, was 5.8 € (Kirkko, 2007). These figures speak for themselves.

7. Conclusion

There is a technological gap that the fundraising organisations should strive to reduce and, if possible, eliminate, and that is the use and integration of advanced elearning technology in their modes of solicitation and strategy planning. Although volunteer work and activities might be partly effective in augmenting below-par e-incomes during times of economic depression, it is our conviction that the neglect of the vital role that elearning can play in motivating donors and encouraging them to continue with their donations, will ultimately subvert and endanger the good relationship that traditionally prevails between donors and the non-profit organisations that they support.

Our research demonstrates that the actual design of the interactive elearning tools is vitally important to motivate and support donors in their conscious process of giving. It is quite possible to substitute self-motivation for face-to-face activity by making use of specifically designed fundraising systems that facilitate positive interactions between donors and solicitation systems. We also demonstrated that the cognitive attitudes of users can be significantly reinforced by intelligent systems that promote optimal donor behaviour on the part of the donor. Such systems need to be designed on ad-hoc basis because of the attitudes and prejudices that people tend to develop by identifying strongly with particular places and circumstances in which certain kinds of behaviour are regarded as appropriate or inappropriate (La Russa et al., 2009).

We also advise designers to use modularity and platform-free software because it is important to reduce costs and the necessity for maintenance in the design of the elearning modules. The design of software based on Java Object Oriented Programming has proved to the very profitable in terms of time saving and the rapid development of new modules and components. The proper design of specific fundraising campaign systems therefore requires experts who are experienced in both elearning and human-computer interactions. Human-machine interactivity (such as refined in computer embedded systems like the RoboBeggar and the InfoKiosk) must be carefully reviewed so that it can be refined and so that the interaction between human beings and the systems concerned can be made as efficient as possible. The modularity of the components is absolutely essential if one wants to design time-saving systems. It is also necessary to pay careful attention to the way in which the surveying tools are organised (this caveat includes the collection of metadata).

The research that we conducted reveals that anthropomorphic robots (such as the RoboBeggar) can be very effective with and attractive to that part of the public who are potential donors, and that they are extremely effective in stimulating affective reactions (La Russa et al., 2009). They do, however, need to be located and used in *open* public (secular) places where their presence will not be regarded as somehow intrusive and inappropriate. We have already indicated how the anthropomorphism of the RoboBeggar can stimulate adverse reactions in sacred places and spaces. In such cases, alternative non-anthropomorphic systems (such as the InfoKiosk) can be used as an effective substitute – provided that those elements that might be regarded as too human, are thoughtfully eliminated. For practical reasons, the dimensions of the fundraising tools need to be suited to the intended usages, the places of collection, and any other predictable working conditions. The best way to create a functional elearning integrated fundraising system is to apply the ADDIE methodology (Analysis, Design, Development, Implementation and Evaluation – Kruse, 2009), and to keep one's focus as a designer on the primacy of the envisaged user's needs and expectations, and not to allow one's own expectations and assumptions to dictate the process (Norman, 2002).

Most online systems will, in the near future, benefit from the use of touch screens. It is much easier to access and use software by means of touch. The time is not far off when most systems will be directed by simple human interactions such as the touch of our fingertips, and the use of the mouse and the click will become largely redundant.

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Publications PAPER II

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When a robot turns into a totem: The RoboBeggar case

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1. Introduction

After her kingdom had been devastated by a prolonged famine in 1649, Queen Christina of Sweden commanded that wooden "beggar" statues be set up in the entrance of churches to collect money for the poor (Saariholma (a), 2001). Figure 1 shows two surviving examples of these wooden begging statues. These statues, known as "begging man/men" (*vaivaisukko* or *vaivaisukot* in Finnish), have slits through which donors are able to push coins. They continued to be used under the Russian domination of Finland and were, until a few decades ago, quite a common sight in the west of Finland where people still used them to deposit charitable donations. One hundred and eight examples of these wooden beggar statues are currently extant (Santaholma (b), 2001). Of these, only one, in the Lutheran Church at Soini (Etelämäki, 2000), has female features (Fides, 2002).

Fig. 1. Two wooden begging statues (*vaivaisukot* in Finnish)

A decision was taken with 3rd sector at the University of Joensuu in 2002 to research the potential of the RoboBeggar as a fundraising tool and to combine that research with the university's R&D program in the field of human-robot interactions. The initial design of the RoboBeggar prototype was limited in some ways by its intended similarity to historic Finnish *vaivaisukot*. It was in fact the original intention of the designers to construct a robot that the public would immediately recognize as being similar to the ancient wooden statues that were once a common sight in the porch entrances of Lutheran churches (Fides, 2002; Kouvolansanomat, 2001; Wanha, 2007). One of the aims of the research project was also to determine the extent to which the classical Finnish *vaivaisukko* that was used in earlier centuries to raise funds for charity might be replicated and modernized as a digitally controlled humanoid robot.

We devised a series of research questions to highlight the educational and technological advantages of the planned robot over the traditional *vaivaisukko*. Table 1 compares certain salient features of the traditional *vaivaisukko*, the RoboBeggar and two other electronic fundraising systems. The table elucidates how two fundamentally different technological fundraising systems illuminate specific issues and motivations in RoboBeggar research. Column 4 indicates the features of the online fundraising system (Online UNICEF) that is used by the United Nations Children's Fund (UNICEF) to raise funds to finance activities such as the construction of schools in Africa or to buy mosquito nets for people who live in malarial areas (UNICEF, 2007). Column 5 shows how the Securegive "Hercules" (2007), an automated teller machine (ATM) compares with the other systems when they are used in donation kiosks. The ATM Hercules has been used at various times by the Swedish Lutheran Church and The Swedish Church Mission (Svenska Kyrkans Mission) to receive and process funds for charitable causes (Palo, 2006; Terhemaa, 2006).

Feature/Function	Vaivaisukko	RoboBeggar	Online UNICEF	ATM Hercules
Interaction	No	Yes	Yes	No
Ease of donation	Yes	Yes	No	Yes
Ability to act as a reminder to donate	Yes	Yes	No	No
User learning support	No	Yes	Yes	No
Emotional appeal	Yes	Yes	No	No
Donor satisfaction	No	Yes	Yes	No
Donor encouragement	No	Yes	No	No
Ability to stimulate a repeat donation	No	Yes	No	No
Digital illiterate	Yes	Yes	No	Yes

Table 1. Comparison of four fundraising systems

Table 1 also highlights features that researchers need to include in a robot so that non-expert users might be encouraged to make donations. One of the axioms of this kind of research is that it is necessary to support interactions with online help (Mondi et al., 2007; Swan, 2004) so that users will be *encouraged* to donate while simultaneously being *rewarded* with some degree of personal feedback and gratification.

The physical dimensions and the appeal of the robot were dictated by the fact that the hardware had to be both *anthropomorphic* and *relatively small in stature* in comparison with the average human being. The height of the RoboBeggar was therefore fixed at 150 cm. The robot also needed to be able to collate information by means of visual, aerial and hypermedia devices that could create and process fundraising target data, statistics, graphics, sociological data, and other specific interactions. The robot also needed to be capable of giving e-learning feedback to users about fundraising targets and goals, the reasons for the fundraising, the targets fixed by the local community, and the reasons why it is ethical to donate money to help needy people. The design of the software was conceptually complex because it was necessary for the money-collecting functionality to operate in combination with the e-learning functions so that users could complete the donation process with ease. A full-graphic and intuitive donation interface was designed for this purpose. The use of "plastic money" (i.e. bankcards) added features to the hardware (namely a bankcard reader for donations), and these posed some interesting problems about the desired resemblance to the *vaivaisukko*. We also decided to give the anthropomorphic robot a female rather than male form even though only one female *vaivaisukko* survives in Finland. We justified this decision by pointing to the fact that it is mainly women who bear the material and occupational brunt of poverty in developing countries throughout the world (De Haan & Lipton, 1998; Hulme et al., 2001; Harcourt, 2001). And since the usability tests of the robot were mostly scheduled to be undertaken at fundraising events on behalf of developing countries, it seemed a natural choice to make the robot female in appearance.

In early Spring of 2004 the female (i.e. *gynoid*) robot called RoboBeggar (the term gynoid is derived from *gynē*, the Greek for woman, and the –oid suffix which indicates similarity in English) was tested in experimental circumstances in the Kupittaa Mall, an urban shopping mall in Turku (the main town on the southwest coast of Finland), which is frequented by a large number of users. The robot was set up to the one side of the walkway of the main hall of the mall so that it would be visible to and accessible by the thousands of people who shop daily in the Kupittaa Mall. The OP Bank Group (the largest financial services group in Finland, known by their acronym OKO) graciously cooperated by funding the basic transportation costs of the robot and by allowing the robot to be situated next to their bank in the Kupittaa Mall. The Cancer Association of South-West Finland (*Lounais-Suomen Syöpäyhdistys* or LSSY in Finnish) was designated as the beneficiary of the robot's fundraising activities.

In the paragraphs that follow we describe the basic architecture of the robot, the adjustments made to the software on the basis of experience, the logistics and agreements concluded for the conduct of the research, a description of how the robot was run. We also evaluate the effectiveness of the robot as a fundraising tool, undertake an analysis and evaluation of all relevant collected data and, finally, draw conclusions about what kind of procedures might work best in future interactions between human beings and fundraising robots.

2. The RoboBeggar architecture used in the Kupittaa event

The architecture of the robot in the Kupittaa event was essentially the same as it was in June (Faggiano & La Russa, 2004) and September 2003 (La Russa, 2009), with the main variations being the touch screen interface and the audio components. Figure 2 shows a schema of the robot architecture and its activity flow. The robot, which consisted of a combination of software (for internal and external operation management) and hardware, had the following components:

(1) *The software*. The software manages and controls both the programmed behaviour and the communications that take place among the robot's components and between users and the transaction system. The e-learning module (*e-module*), which creates a connection between fundraising requirements and the necessity to heighten donor awareness, sympathy and response, presents a condensed version of essential information about the cancer organization that is the beneficiary, the disease itself, its incidence in Finland and the extent to which children are at risk of contracting cancer.

(2) *The touch screen*. The touch screen is the interface between the users and the robot and presents the e-learning information in modular form. The touch screen gives users the option of selecting their preferred operation. The options are to donate funds, to be presented with more information or to close the transaction.

(3) *The bankcard reader* (or card reader). The card reader is an electronic device that is capable of reading the magnetic tape of bankcards. If a user decides to make a donation, software transmits the information provided by the user to the bank. The bank then responds by setting up secure conditions for the transmission of data so that the user's donation can be received by the fund. The user is then given an opportunity to select the precise amount of the donation in a simplified window (see Figure 3 for details). The window allows the user to make a donation only in accordance with predetermined donation amounts (i.e. 1, 2, 5, 10, 20, 50 and 100 €). The RoboBeggar and the bank system are connected by means of GSM connection.

(4) *The sound card and the speakers*. These are necessary so that the robot can talk and so give audible feedback to donors. The robot's ability to speak makes its resemblance to a humanoid more convincing.

(5) *The printer*. The printer offers the donor a printed receipt which functions both as a receipt and as a reminder of the donor's charity. Although the printer is actually a constituent part of the bankcard reader, external separate equipment could just as well be used to produce better quality printouts.

(6) *The micro controller and the servomotors*. The servomotors, which move the arms and head of the robot, give continuous feedback to the software about the latest position and situation of the robot. The servomotors are controlled by a programmable microchip (a micro controller) that receives orders from the software through a serial port. The software commands are "interpreted" in the micro controller and transformed into motor action. The RoboBeggar is capable of gestures that are correlated to the sound card and to a speakers' activity.

(7) *The robot shell*. The shell, constructed from twelve bolted aluminium plates, provides the robot with a body to which the limbs and head are attached. The computer and its components, the micro controller and the loudspeakers, are all allocated space inside one of the two chambers into which the shell is subdivided. The shell can

easily be disassembled in its two constituent parts: the lower and upper sections (which hold the limbs, the head and the touch screen structure). All the servomotors are located inside the tubes that comprise the limbs and the neck with a total of 6 degrees of freedom (DOF). In engineering and mechanics (as well as in robotics), a *degree of freedom* defines the capacity of a rigid body to rotate on one of its axes or move along it (Zhang et al., 2007). Since rigid bodies have three axes, the maximum number of DOFs in a three-dimensional rigid body is 6. It is obvious from this that the DOF of systems such as robots can increase to a higher number (the human arm alone, for example, is considered to have seven DOFs).

Because the software is the core and heart of the robot, it needs to synchronize the robot's motors with its speech so that the robot's speech might appear to be as natural as possible. It also needs to take care of the e-module flow and to ensure that any bankcard's communication data will be transferred securely and efficiently.

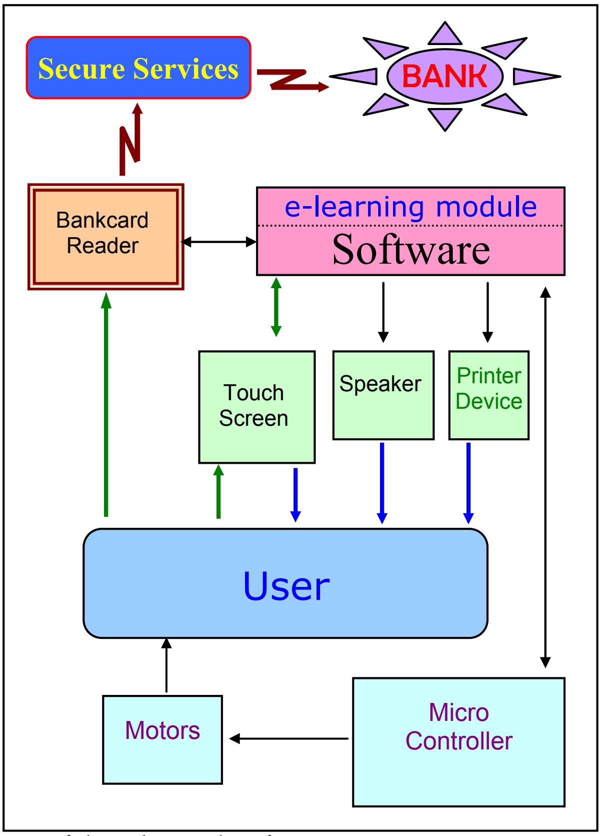

Fig. 2. The architecture of the robot and its functions

3. The RoboBeggar in the Kupittaa Mall experimental event

The choice of giving the robot a gynoid appearance was not motivated by sexist considerations but by the relative success of women in media and communication (Stratton, 2001). Because it has been proved that robots make a positive educational impact in learning environments (Pfeifer, 1997; Miglino et al., 1999), the gynoidal appearance of the RoboBeggar should be considered to be a compromise between an indigenous Finnish tradition (Santaholma, 2001; Fides, 2002; Etelämäki, 2000), technology (Naidu et al., 2002; Papert & Harel, 1991; Vo et al., 1995; La Russa et al., 2004) and sociological studies that privilege and showcase the role of women (De Haan & Lipton, 1998; Hulme et al., 2001; Harcourt, 2001).

3.1 The robot interface

Because the user interface had to be as simple as possible (Marwedel, 2003; Cooper & Reimann, 2003) while offering a highly intuitive interface for the e-learning module (Norman, 2002), the LSSY was asked to express their preferences about the style of graphic interfaces and the information that they would present to prospective donors. Because LSSY is experienced in fund-raising activities and possesses accurate information about their average user interaction time (estimated to be approximately 60 seconds for the human-robot interactions) (Card et al., 1986), the e-learning module was reduced to four basic informative windows (see Figure 4, 5, 6 and 7) with additional direct access to the iconic window that mediates the donation activity (see Figure 8). Three other windows were dedicated to the human-robot introduction (the welcome window – see Figure 3 for the template) and the donation process (see Figure 9 for an image of the bankcard reader information window). The remaining (final) window of the donation process thanks the donor with a text that is randomly extracted from a list of twenty possible choices.

The use of the euro icons was dictated by the fact that it is necessary for users to be well-informed about the size and value of the monetary value of the donation that they intend to make (Huang et al., 2002) – in spite of the limited time at their disposal for making a decision. The euro icons make it easy for a donor to choose the size of the donation according a progressive ascending value order from left to right and top to bottom. The icons were also visually weighted and distributed in the iconic window in accordance with their representative values (see Figure 8).

Fig. 3. The welcome window template

Fig. 4. The main LSSY window which introduces the *campaign to eliminate cancer*

The frame of Figure 4 reads "*Voluntary Work to Fight Cancer*" (*Syöväntorjuntatalkoot* in Finnish). The buttons are programmed with the following links:

(1) "Syöpä?" (*cancer*) leads to the e-module "Syöpä lyhyesti" (*in brief about cancer*). See Figure 5.

(2) "Lasten syövät" (*kids' cancers*) leads to the e-module "Lasten syövät" that is shown in Figure 6.

(3) "LSSY ry" leads to the descriptive e-module of "Lounais-Suomen Syöpäyhdistys" organisation (*The Cancer Association of South-West Finland*) that is shown in Figure 7.

(4) "Takaisin" (*back*) is for going back to parent e-module.

(5) "Käyttöohjeet" (*instructions*) leads to the system usage information e-module. In the other e-modules this button is substituted by "Lahjoittaa" (*make a donation*) which straightly leads to the iconic window of Figure 8.

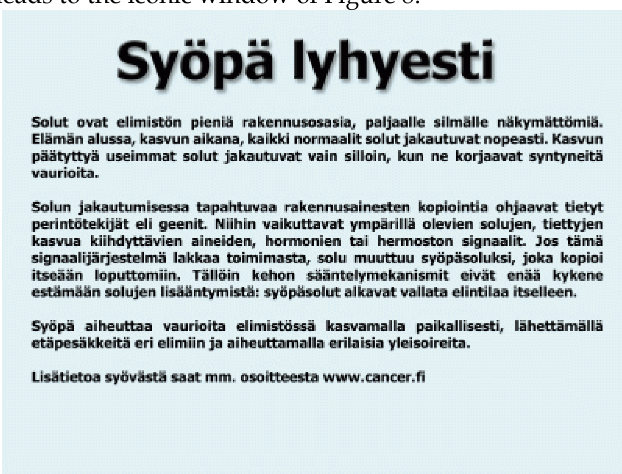

Fig. 5. A brief overview *about cance*r

Fig. 6. An explanation of how *Children get cancer*

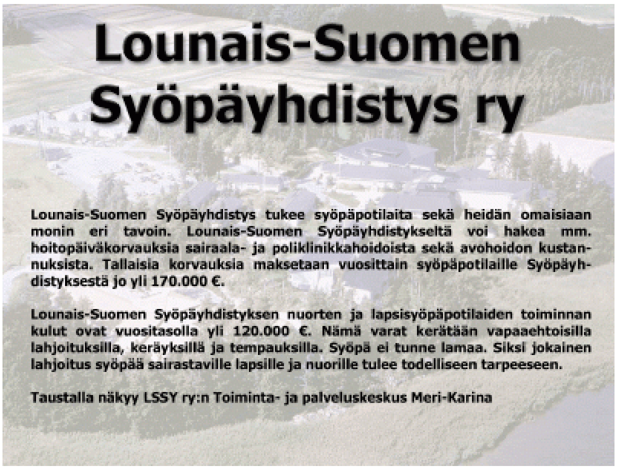

Fig. 7. The window describing the *Cancer Association of South-West Finland*

The *iconic window* of Figure 8 informs the user of the opportunity to donate a given amount of money by touching the correspondent monetary icon. It also tells that after having chosen a donation value a new window (see Figure 9) will guide through the bankcard operation to complete the donation process which would be confirmed by the robot. The confirmation is given via receipt printing and a final informative e-module containing the donation data (the current user's donated amount as the overall donated amount), some extra activity hints and the verbal thanking of the robot.

Fig. 8. The *iconic window* controlling the donation process

Fig. 9. The bankcard reader information window with written instructions

3.2 How the RoboBeggar was used in practice

The LSSY was entrusted with the care and public management of the robot for a period of two weeks in late February 2004, and as much information as was considered necessary was given to the representatives of the bank and the cancer organization about the software and hardware of the robot. In addition to this, the robot's software was simplified compared to previous usage events because it was too expensive for the robot's designers to manage the robot directly themselves (the distance between the research institute and the mall was about 600 km) and because there were no available local robotic technicians to undertake the task. The designers therefore automated the uploading of the robot software to coincide with the initialization of the computer system so as to obviate as much as possible the need for any kind of direct administrative management of the robot.

The economic need to create a partly self-managing robot that was not under the direct control of the academic staff nevertheless created some unexpected consequences that gave its designers additional socio-cultural data that they were obliged to take into consideration when considering how they might modify the robot to cope the range of likely human-robot interactions in the future.

3.3 Data and feedback information

The robot, suitably attired in woman's clothing, was eventually carefully positioned next to the OKO Bank on the one side of the main hall of the Kupittaa Mall. From that position it was possible for the bank's employees to observe and monitor what was happening to the robot from their own work stations. The robot was switched on in the mornings and off in the evenings by means of an electric cable that was connected to the main power supply of the bank. Members of the LSSY organization volunteered to stand near the RoboBeggar so that they could help and encourage passers-by to approach the robot and begin a human-robot interaction.

On the eve of the usage period the research team assembled and tested the robot in situ in Kupittaa Mall and briefed those members of the bank's staff who would be involved in the care of the robot with whatever they needed to know about the running of the robot (such as its activation and deactivation, and its stability). OKO Bank also took responsibility for maintaining the integrity and safety of the robot. The management of the RoboBeggar was then handed over to a representative of LSSY, and everything looked fair for full use and data collection starting the following day. The robot was positioned with its back to the bank and its front toward the mall pathway. This was the prelude to two weeks of testing and fundraising that would follow.

What follows below is a description of the event feedbacks that were obtained from three different sources: (1) the OKO Bank's employees, (2) a local newspaper article, and (3) the Multiple Choice Question forms that were intended to be offered to donors.

3.4 Feedback from the employees of the OKO Bank

Three employees of the bank reported the following information during the course of interviews:

(1) For unknown reasons and at unpredictable moments the robot would stop functioning. This made it necessary for the LSSY attendees to restart the robot's program by unplugging and then plugging in the power cable again.

(2) In the first few days tens of people interacted with the robot and made donations through the medium of the robot.

(3) Even while the robot was functioning, hundreds of people approached the robot and the LSSY attendants because the RoboBeggar's had attracted their attention with its rather distinctive voice calling from the speakers (the axis of the pathway in the mall was only about ten meters away from the place where the robot stood).

(4) Fewer than twenty people experienced difficulty in sliding their bankcards through the bankcard reader slot at a speed that would allow the magnetic tape to read the data on the bankcard. Sometimes this operation had to be repeated to be successful and sometimes people turned to make a cash donation directly to the LSSY attendees who were armed with donation tins.

(5) There was a distinct increase over the period of the experiment in the number of people who were attracted by the RoboBeggar and who approached it either out of curiosity or to make a donation.
(6) After about a week the LSSY volunteers decided to keep the RoboBeggar switched off and resorted to collecting money by using only the LSSY donation cans. They did this because they said that the robot had already become known to the users of the mall and because many of them were approaching the robot before it had even called them. The LSSY volunteers also eventually concluded that it was easier and simpler for them to collect money directly in donor boxes than to wait for users to complete the interaction processes. In the meantime an additional vest that displayed LSSY fundraising information (see Figure 10) was placed over the robot's chest.
(7) During the sixteen days of the fundraising experiment, many hundreds of people came over to examine the RoboBeggar and to ask about its function, and these people collectively donated thousands of euros to the LSSY organization.

3.5 Feedback from the local newspaper

During the experiment the local Turkulainen newspaper published an article (Pitkänen, 2004) that described the fundraising robot and offered opinions about its functions and usability. The picture in Figure 10 accompanied this article and it is reproduced here with the permission of the newspaper. The article highlighted the following points:
(1) People perceived the gynoid as a charming lady with green eyes that focused on passersby. (Author's note: For this experimental event, the robot had been repainted for a third time. This inspired the research team to consider the possible future use of intelligent tissues, which are substances capable of reproducing humanoid skin-like behaviours.
(2) The calling voice of the robot proved to be so effective in attracting people that its volume had to be reduced. Many passersby became alarmed because they thought that a real person was in some kind of trouble and approached the robot area offering their help.
(3) The robot had very good manners and would thank people courteously for their donations.
(4) The use of “plastic money” was a necessary component in the fundraising campaign because many people who did not carry cash wished nevertheless to make donations.
(5) The robot offered people a choice of beneficiaries for their donations (i.e. they could specify whether their donation should be diverted to child or adult care).
(6) The robot was not capable of carrying out a conversation (dialogue). It was evident that donors had an emotional need to tell the robot about their own experience of cancer.
(7) The robot was occasionally switched off.
(8) LSSY attendants supplemented the fundraising activities of the robot.

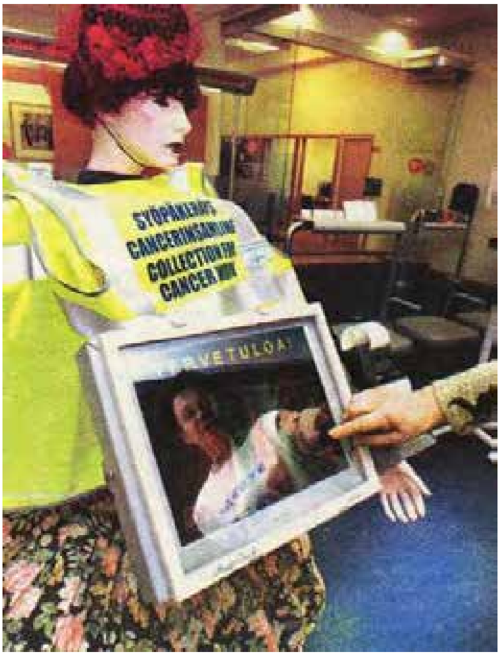

Fig. 10. The RoboBeggar in its LSSY vest (still in active mode)
Photograph reproduced by kind permission of the photographer, Pasi Leino.

3.6 Feedback from users

A Multiple Choice Question (MCQ) form was designed to be offered to people who approached the robot and who had initiated an interaction process. The form was intended to provide the researchers with additional data for analysis and evaluation. The information collected by the form related to:

(1) Gender
(2) Age group
(3) The functionality of the robot (seven questions)
(4) The effectiveness and influence of the robot (four questions)
(5) User evaluations and assessments (five questions)
(6) The donation system application (four questions)
(7) A blank space for any additional messages to the researchers and/or the designer of the robot (users were instructed by a message in bold letters at the bottom of the front of the form to write any additional personal contributions on the reverse side of the form).

According the type of question being asked, users could respond in one of two possible ways (Uebersax, 2006):

(1) They could express their opinion in terms of the following scale:
  1 = completely of different opinion
  2 = partially of different opinion
  3 = it cannot be determined
  4 = partially of the same opinion

5 = fully of the same opinion

(2) They could choose one of the following three options:

No

It cannot be determined

Yes

Only five multiple-choice feedback forms were returned to the research team by the LSSY volunteers at the conclusion of the fundraising test campaign. The reasons for this poor feedback are explained in the following section.

4. Analysis and assessment of the data material

It was a defect in the research design that the LSSY volunteers focused mainly (if not solely) on fundraising to the exclusion of a prior agreement also to collect research data. The research element would have involved them in encouraging users to fill in the feedback forms which were designed to provide vital information about the way in which the RoboBeggar was being used. If a similar misuse of the robot is to be avoided, communication between the research institute and the LSSY needs to be much more clear and unambiguous. If communication had in fact been clearer before the test event, the necessary users' feedback information would have been collected (Pitkänen, 2004).

The feedback that was collected provided a variety of data relating to different aspects of how the robot was used and how users approached it. The feedback obtained comprised 75 answers to questions about the quality of the robot's functions and its efficiency, and 15 expressions of personal opinion. The analysis in the graphics in Figures 11, 12 and 13 are presented as percentages of the related data population. Most noteworthy among the results is the following feedback obtained from an analysis of user responses (set out in comparison with results obtained from a previous test event in June 2003 (La Russa et al., 2004) :

(1) When users were asked to express an overall opinion about the functionality of the robot (the user interface, the donation process, the provided information, etc.), 74 % of their replies pointed out that it had been totally successful, and 23 % that it had been successful (see graphic in Figure 11). In a previous test event carried out by La Russa (La Russa et al., 2004), the corresponding values had been 78 % for totally successful and 15 % for successful.

(2) When asked their opinion about whether the robot was successful in its interactive tasks, 80 % of responses were yes and 20 % were no (see Figure 12). In the previous test event, 94 % of the answers were yes and 6 % were unsure.

(3) In response to a question about whether the robot had been successful in creating a "fun" situation, 40 % of the answers indicated that it had been totally successful while 60 % indicated that it was successful (see Figure 13). In the previous research event by La Russa, the corresponding values had been 78 % for totally successful, 14 % for successful, 4 % for unsure, and 4 % for totally unsuccessful.

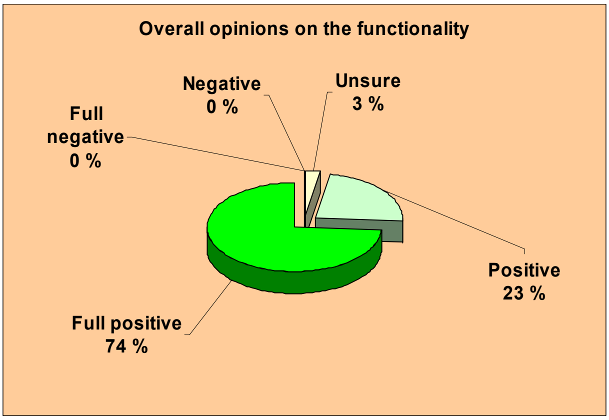

Fig. 11. Users' assessments of the robot's functionality

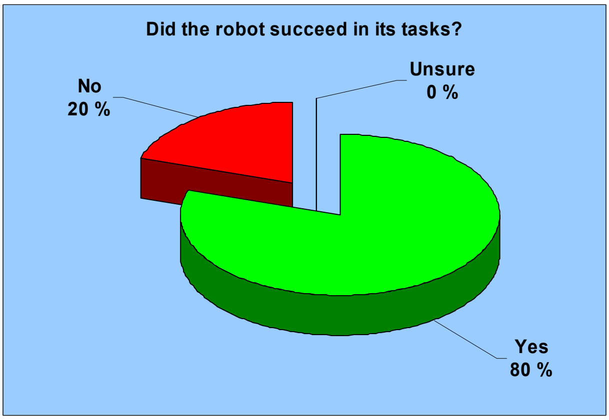

Fig. 12. Users' assessments of the robot's success in carrying out its tasks

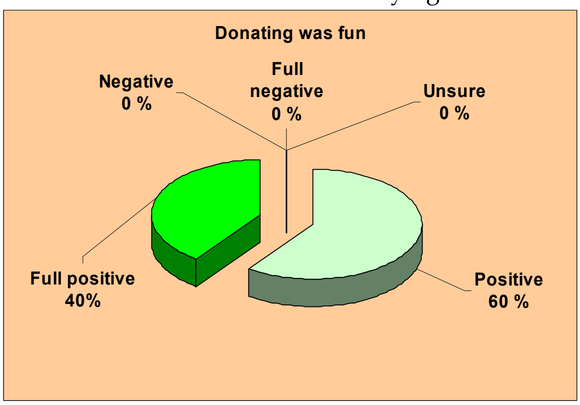

Fig. 13. The extent to which users enjoyed using the robot to make a donation

The researchers introduced a new set of questions for the Kupittaa Mall test event to evaluate users' perceptions and their appreciation (or otherwise) of the robot's donation system features. Figure 9 displays the results (45 % of the answers were a global positive response and 35 % a global negative response).

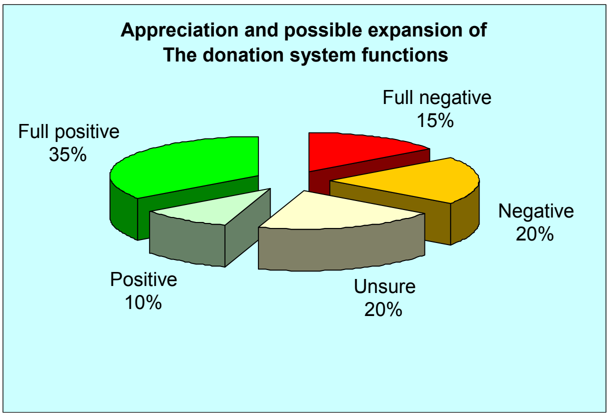

Fig. 14. Users' appreciation of the robot's donation system application and potential for expansion

The feedback obtained from participant OKO Bank employees and the Turkulainen newspaper tended to be in agreement: users initially perceived the robot as a living being and then, when it had become inactive, as a catalyst for emotional reactions and conceptual creativity.

5. RoboBeggar as a digitalized totem

It was noticeable was that the robot had so stimulated a number of passersby that they wanted it to act as a confidant with whom they could verbally share their experiences. The emotional reaction of people towards the robot was in fact so strong that many experienced it as *almost* human (Pitkänen, 2004). The calling voice of the robot was so successful in attracting the attention of passersby that many felt compelled to come to its aid (they assumed that the robot was in fact a person in trouble and they came to question the LSSY volunteers about its function).

During the first week of the fundraising campaign the robot made a strong social impact on passersby who knew about the its presence, purpose and role as a technological agent for raising funds for combating cancer. The RoboBeggar had thus in fact become a successful catalyst for collecting funds for the fight against cancer. Even after the LSSY had switched the robot off, the RoboBeggar continued to create a strong *momentum* as a catalyzer or emotional totem that served the interests of the cancer-fighting organization (Gareth, 1997). The LSSY participants *adopted* the robot by dressing it as one of their volunteers and by using its undoubted attractiveness to encourage people to make donations (Figure 10 shows the striking yellow LSSY vest with which the robot was clothed). The existence in people of unconscious ideations that can be concretized in, for example, symbols or totems has already been widely studied in psychological, sociological and educational research (Starr-Glass, 2004; Fiske & Fiske, 2005). The Merriam-Webster's Dictionary defines **totem** as *an object (as an animal or plant) serving as the emblem of a family or clan*. This definition implies that the RoboBeggar achieved the status of a totem.

Despite occasional failures in the technological functioning of the RoboBeggar, valuable information was nevertheless collected from the three means of feedback about donor behaviour and attitudes towards the robot. That data confirms that the robot's humanoid appearance and verbal skills were successful in affecting the emotional and cognitive behaviour of the people who came into contact with it. After it had been there for a while, the robot even began to assume a living role in the imagination of people who frequented the mall. People accepted the role of the robot as a catalyst in the campaign against cancer and as a means that people could use to make donations to combat the disease. In other words a purely technological robot was accepted by people and transformed into a highly emotive social totem.

6. Conclusions

Despite some unwanted and unforeseen conditions and events, the robot RoboBeggar received mainly positive reactions from users with regard to its functionality, its interactive tasks and its ability to create fun and amusement during the interactive learning process. The robot was successful in its essential fundraising and supportive purposes.

An analysis of the assembled data (from interviews, the newspaper article and from user and participant feedback) highlights the reasons why and the mechanisms by means of which the robot was transformed into a social totem that elicited some highly emotional reactions. It is apparent that the humanoid appearance of the robot and its verbal skills and appeal were among the main elements that elicited emotional responses from people and influenced their subsequent behaviour. This research tends to confirm that is through the agency of human imagination and perception that a robotic tool (in our case, the RoboBeggar) can be transformed into a totem of social value and effectiveness. It also became clear to the researchers that it is not only design and implementation that are important for the successful operation of a fundraising robot but that the robot's self-presentation and social aura are also crucially important factors for an overall understanding of why such a robot may be successful. The test case conducted in the Kupittaa Mall clearly shows how presentation and social aura compensated for the partial failure of the RoboBeggar's implementation. It is also clear that interpersonal and cultural elements influenced the way in which people perceived, accepted and responded to the robot as a potential personal interlocutor.

It is now clear that future developers of this model might do well to look at the possibility of technological improvement in the interface and e-learning modules. It is also clear that additional studies are required to investigate the emotional and psychological responses of users to advanced technological equipment that elicits emotional responses in human beings. It is also fundamentally important to be able to define exactly how influential both the hardware and software are in human-robot interactions so that effective guidance can be given to the designers of anthropomorphic robots of this kind. It is also important to be able to define the effect that particular physical environments and locations have on the efficiency of a humanoid robot's function so that it will be possible to place a robot in optimal situations for interacting with human beings.

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Publications PAPER III

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Avatar Aided e-Learning Fundraising System

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Abstract

This paper is about the role of advanced educational tools in fundraising and presents a design solution meant to assess by comparative evaluation the human-machine and human-computer interactions in the case of the fundraising Robo-eLC. The software core of the gynoid robot and its elearning system have been re-modulated based on feedbacks from earlier prototype and integrated into a multimedia kiosk. An avatar is integrated in the new user-interface system to partially substitute the missing gynoid robot and support the users' elearning processes. The ongoing tests' results of the new software show specific efficiencies and deficiencies of the Robo-eLC as fundraising educational tool. The described approach constitutes a viable verification method for the functionality design of the anthropomorphic robots meant for elearning and fundraising activities.

1. Introduction

The successful use of emerging technologies for the creation of advanced educational tools requires not only the adoption of proper scientific methodologies (Instructional Systems Design (ISD) models such as ADDIE's [1], Dick & Carey or others [2]) but also coping with the frequent problems raised by the validity verification of advanced educational tools' integrated multidisciplinary approaches [3][4]. Most of these validity verification problems are due to the fact that the tool's concurrent scientific (and technological) sectors do not usually have interdependent known solutions. Researchers and developers are often forced to define new approaches to assess and solve their educational user-centered design problems [5].

Based on known wooden beggar statues [6] *vaivaisukot* (the Finnish plural of *vaivaisukko*, meaning "begging old man") established in Finland since 1649 and that used to be located by church proximities for money collection in favor of the poorest, an anthropomorphic gynoid (the term gynoid is derived from gynē, the Greek for woman, and the –oid suffix which indicates similarity in English) fundraising robot (the *Robo-eLC* [7]. where the term stands for "robot for e-Learning and e-Commerce activities") was designed and constructed. The Robo-eLC was capable to collect money via bankcard reader and incentivize users' acquisition of information and know-how. The interacting robot was meant to study human learning behaviors in the process of donating for charity purposes and define design principles for the creation of efficient fundraising robots. The robot's software and learning modules were adapted to each test event and collecting purpose [8]. The robot clothes and appearance were modified according to the donation targets or represented population. People's interactions with the talking robot were observed and users' feedbacks were collected during four different test events [7]. Surprisingly the robot received most of its negative reactions or even remained ignored during a usage test case that was conducted in a church [4]. The collected feedback data, the observations and the interviews [7] led the researchers to look for further information on the possible motivating or discouraging factors that could influence the human-robot interactions within given specific use environments.

Having sufficiently exploited the robotic scientific research set goals, the acquired user-robot interaction information and data had to be verified or corroborated by complementing alternative test cases. In other words a new fundraising approach had to be conducted

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in similar test cases and conditions to prove or confute the validity of the robotic multidisciplinary approach.

Figure 1. The InfoKiosk and a donating customer

Hereby is described the *verification* approach that is based on the use of a multimedia pillar kiosk to be adapted for elearning fundraising purposes (from now on referred to as *InfoKiosk*). Figure 1 shows the InfoKiosk in use with its new running avatar aided software.

2. Overview on the Robo-eLC test cases

During a period of two years the Robo-eLC was tested in four different occasions. In each occasion the donation targets required the creation of new elearning modules composed of audio elements (for the talk of the robot) and visual data (target information, statistical data, descriptive pictures and photos). The test case events and the relative summarized results were:

1) June 2003, mission organization gathering by Arena sport stadium. The donating targets were set for three different countries (Ethiopia, Mongolia and Venezuela). The robot was dressed like an old Finnish lady. 97% of the users expressed positive opinions on the functionality of the robot [7]

2) September 2003, fundraising for Tanzanian education and health purposes within the premises of a bank. The robot was dressed with Tanzanian traditional clothing and made look as an African lady. Few interactions and users feedbacks. Interviews highlighted the importance of the environment conditions/purposes on the use efficiency and impact of the robot

3) February-March 2004, fundraising for cancer organization. The robot was located in a mall and vested as a fundraiser of the organization. Interviews and users feedbacks highlighted the phenomenon by which the robot turned into an emotional totem [7]

4) December 2004, Christmas carols collecting within Church premises according the national scheme of the Finnish Evangelical Lutheran Mission for four different countries (Angola, Israel and immigrants in France and Germany). The robot was dressed like an old Finnish lady as in test event 1). Basically the robot was neglected by the adults. The observation of people's behavior highlighted a sort of environment-related robot-phobia, also supported by three interviews made to church personnel.

2.1. The robotic shortcoming in the church

The series of the three first test events had provided enough information to formulate hypothesis on the lack of acceptance (and therefore refutation of the robotic role as fundraiser and educational tool) by the people in the last test case event. The interviews and users' feedbacks showed that people felt that the robot did not belong to the church physical environment and was seen and felt as an intruder. The environmental human-machine descriptions of the collecting events show the same situations where users moved around the Robo-eLC leaving a void area of about three meters in radius. Children were an exception being the most enthusiastic in approaching the robot and starting interactions.

To set a paradigm with justifiable design criteria for anthropomorphic elearning fundraising robots a new set of tests was therefore required where the robot should have been absent. The next section describes the chosen solution for conducting the comparable tests.

3. The Avatar aided fundraising system

Thanks to the software modularity aspects of the Robo-eLC and its Object Oriented Programming structure based on Java language [9], the core software of the robot was updated to host an avatar that would simulate and represent the *vaivaiseukko* (female form for vaivaisukko) hardware. The multi-threading capability of Java [10] allows the simultaneous running of the avatar and the management of the software interacting resources. The new user interface was remodeled to leave room to the avatar without disrupting the existing modular basic structures for the interacting browsing buttons, test fields, photos' or data (diagram, tables and so on) areas [11][12]. Figure

2 shows a screenshot of the new software.

The avatar is designed to be synchronized with the elearning modules of the software and follow the user interactions with the system by talking and expressing emotions according to the due situation. The avatar is capable of expressing eight different conditions: greeting (used at the beginning of the interaction and when is needed to attract users' attention), standing-swinging (waiting for users' actions), happy (jumping of joy), sad (when a donation is interrupted or unsuccessful), generous (holding a gift box in occasion of users' intention to effectuate a donation), bored (when the system is in idle with activated screensaver) and talking (when it communicates verbally with the users). A typical sequence of avatar behaviors is the greeting followed by talking then showing a gift box and jumping of joy for a successful donation.

Figure 2. The avatar in the user interface of the InfoKiosk

3.1. The assessment elements for the user interface

The software that is used in the InfoKiosk is based on the main frame that was used with the Robo-eLC. The modifications are not going to be perceived by users except for what concerns the avatar presence. Due to the fact that there is no more a robot, users should be free of the previously observed aversion to the robotic presence in the church premises. The collected data will therefore be screened to highlight the needed information to assess the two different impacts given by the InfoKiosk and the Robo-eLC. The InfoKiosk feedbacks' related analysis will also give information concerning the avatar appreciation, the pillar kiosk used to create the InfoKiosk and the emotional behavior of the people in relation to the fundraising arguments.

Observation schemes will be used for the InfoKiosk to compare its test cases to the Robo-eLC's. The following elements will be registered in the observations:

- The test event occasion and its social value
- The total number of present people and the age distribution
- The behavior of the people in the nearby of the InfoKiosk
- The behavior of the forming groups of people and their actions in relation to the InfoKiosk
- The behavior of the individuals that approach the InfoKiosk

In addition to this, users' answers to a questionnaire of 19 points will be collected. The questionnaire is prepared to highlight the role and influence of the avatar and provide assessments elements on users' appreciation of the fundraising system. These elements can be summarized in four main groups:

- The functionality of the system and the interactions with it
- The efficiency of the elearning modules and the role of the system in making a donation decision
- The avatar and its importance in the InfoKiosk
- Self assessment on learned issues and behavioral attitudes

The InfoKiosk will also provide metadata concerning the donation targets and users' preferences in the browsing of the interactive system.

3.2. Visual parallelism and audio elements

The role of the work environment where the InfoKiosk should be used is quite fundamental in affecting users' behaviors and consequently their learning attitudes. This was already noticed in occasion of the use of the Robo-eLC [7]. For these reasons the InfoKiosk will be tested in similar conditions and same location where the Robo-eLC was used. The dimensional visual impact varies slightly in volume while the physical occupational factor is equal. The point where we expect a drastic variation is in the impact of the form (i.e. the pillar form of the InfoKiosk versus the humanoid form of the robot) and its role to be assessed.

The internal audio systems of the two cases follow the elearning design concept of support and encourage users in their actions. Even though some of the audio elements have been changed or updated their integrating roles in the running software remain similar. Nevertheless the users' opinion on the audio elements will be monitored and taken into account.

4. Conclusions

The richness of available research in multidisciplinary disciplines and the availability of advanced technology are posing serious questions to researchers that intend to design and develop new tools that are meant for educational purposes. The need for substantiating the criteria for analysis, design, development, implementation and evaluation of the interacting Robo-eLC has forced the authors to look for alternative system (the InfoKiosk avatar aided system) testing cases. It is fundamental to define the educational impact or failure of the robotic appliance in given circumstances and at the same time to obtain valuable information on reasons why people engage with robots and what they learn in the process. As described in this paper, the solution to many fundraising problems passes through users' involvement and education into an active motivated role. It has also been highlighted how the design of an educational tool must take into account users' perceptions and behaviors. Digiphobia or technophobia can have their roots in misunderstanding or genuine ignorance. Nevertheless it is the duty of the designers to find the correct pattern to develop efficient communicating tools/means [13].

We propose in this article a verification method for the functionality design of the anthropomorphic robots meant for elearning and fundraising activities. The ongoing tests will be presented in later publications with analysis results and comparative evaluations. The outcomes of this research approach (notably *a double approach verification with user centered substitution of inferring elements* – i.e. the robot entity substituted by an avatar in a multimedia kiosk) should encourage multidisciplinary researchers to look for strengthening strategies for their tool design and development.

Results of the ongoing research test cases and Focus Group interviews will be object of a coming paper to highlight the elements that contribute to the human-machine interaction and that can be used as a set of design guidelines.

5. Acknowledgemts

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Publications PAPER IV

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4

Virtual humans vs. anthropomorphic robots for education: how can they work together?

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Abstract – **The IT society is more and more dealing with the formation and use of instruments of interactions that can create virtual realities or re-create real environmental situation. The richness and variety of users' interactions can go far beyond the simple sensorial use of the virtual realities. It is now possible to activate behavioral and cognitive learning attitudes, just by taking into account the various components that play a role in the human-computer interactions with a specific care for the sensorial perceptions of the users. Recent technological developments open new perspectives for the cooperation between learners, virtual humans and anthropomorphic robots. This paper analyses, discusses and highlights the added value to the social awareness in a learning community that the properly integration of the 3 mentioned types of actors can produce. A set of directions are also identified for the convergence and integration of the robotic appliances and systems with virtual humans in various educational situations.**

Index Terms - virtual humans, anthropomorphic robots, social awareness, CVEs.

INTRODUCTION

Collaborative Virtual Environments (CVEs) have been widely used in educational settings of different types. CVEs provide virtual spaces for socialization and work by creating interactive and stimulating learning environments. The recent trends show an increased use of "virtual humans" in CVEs for various learning and social purposes. Virtual humans (VHs) can be defined as "two- or three-dimensional human-like animated characters that show emotions, intelligence and that know how to interact with human users" [13]. VHs are digitalized animated human-like faces or figures, allowing verbal and non-verbal communication behaviors, also via body language and facial expressions. Their behavior could be fully autonomous or partly dependent on people's choices, in which case the VHs would act on behalf of the human users. VHs can be used to perform a number of educational tasks, such as providing information services, serving as virtual tutors [13] and dynamically reshaping learning environments according to the changing educational and social needs [15].

Recent research in human-robot interaction [18, 20] stresses the role of robots as collaborative team members, indicating the establishment of social relations between the human user and the robot, where the human can play the roles of supervisor, peer or even bystander. In an educational context the most important type of robots is the *pervasive robots* exhibiting complex behaviors. These robots are in general mobile and capable of emulating human behaviors, in terms of body language and communication. The pervasive robots integrate mechanisms for social interactions, autonomous navigation and object analysis [1].

Though there exist a number of basic similarities between VHs and pervasive anthropomorphic robots (e.g. interactions modes with humans), there have been very few attempts to integrate them into one system. Nevertheless it is possible to exploit the advantages of both approaches. For example, in the Virtual Synergy system humans, agents and mobile robots are mapped into a 3D virtual environment to facilitate an urban search for rescue operations [20]. Virtual environments can be created where robots have virtual representations, or avatars. In such environments, students (who for different reasons could not be co-located with the robots) or VHs (such as virtual tutors) could interact with the robots by e.g. giving some commands. These interactions and behavioral correlations motivate the idea of a learning community where human learners, VHs and anthropomorphic robots are represented, all participating in the learning process.

It is important to stress the fact that supporting social awareness (SA) in a learning community (see e.g. [15]) is of high importance for a correct collaborative or collective learning attitude. SA can be defined as awareness of the social situation in a group or community in a shared environment, including the knowledge on learners' resources, activities and place in social network. Short-term SA is the awareness of the social situation at a certain moment. Long-term SA is the awareness of the social situation in general. This paper will focus on how the SA mechanisms can be extended to a learning community of real and virtual humans and anthropomorphic robots. To support this discussion, the next section provides a scenario illustrating how all the 3 actors can work together in an educational situation. Then, the paper shows how the characterization framework and awareness mechanisms, originally described for human users, can be extended to VHs and further to robots. Further, some directions are given for possible convergence and integration of anthropomorphic robotic appliances and systems of VHs in 3D CVEs in a number of educational tasks. Finally, conclusions and some directions for future work are presented.

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VIRTUAL HUMANS AND ROBOTS WORKING TOGETHER: A SCENARIO

This section considers an educational situation where a robot called Robo-eLC [9] (as a specific case of anthropomorphic appliance) or a similar robot is used in combination with virtual humans in a 3D CVE. This robot allows users to learn and grasp complex concepts, becoming experts in the subjects that the robotic learning modules suggest. The learning modules of this specific robot recreate some world dimensions, related to socio-economic situations in developing countries, but can reproduce almost any kind of information where graphics, pictures, texts, sounds et alter suffice. The anthropomorphic features of the robot facilitate its task of educating users about specific conditions in developing countries (i.e. creating a correlation between the robot dressing and the culture of the represented countries). Users begin their interaction with Robo-eLC through the visual interface (a touch screen) (Fig. 1). They are presented with organized sets of screen presentations through which they receive information on the developing countries, what to do in the ongoing phase and how to proceed into the next step. All along the interaction process the robot talks to the users, giving relevant information or advices.

Let's consider a group of students, partially scattered and partially co-located. All of them are having a class together in a 3D CVE, with a tutor being a VH, teaching a class in geography (see Fig. 2 for an example of an educational session where both humans and VHs are represented). The theme of the specific lecture is developing countries and aid programs. All of the students and the robot are represented in the virtual environment as avatars. Part of the students is located in the same room as the robot, while other students, who do not have the opportunity to be there, interact virtually both with the robot and the co-located students. Both the robot and the co-located students wear different kind of censors, providing a mapping of their relative positions and interactions to the virtual environment.

During the class, the virtual tutor talks about a certain developing country, showing slides and asking related questions to the audience, evaluating students and guiding the discussion. At some point of the lecture, the virtual tutor suggests to interact with the "representative" from the developing country that has been lectured on. The representative (i.e. the robot) is embodied (i.e. physically organized, which might include the dressing and the anthropomorphical modification) according to the country it represents, both in the real and virtual environment. In this way, the students can have a more direct and "embodied" learning experience. All the actions of the co-located students and the robot are mapped into the virtual environment, e.g. their touch screen manipulations and avatar movements, chat transcription of the speech, or a direct audio feed. In addition, both the tutor and the non-co-located students may interact with the robot from the virtual environment, e.g. giving commands or asking questions about the corresponding developing country. The results of this activity is mapped into the real world, while the physical robot takes certain actions and communicates to the co-located students both the argumentation of the tutor or of the other students.

FIGURE 1
A USER INTERACTING WITH ROBO-ELC

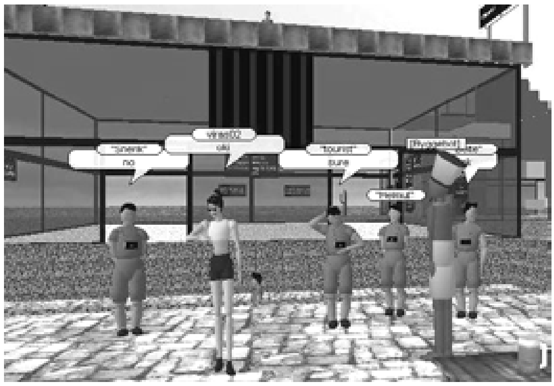

FIGURE 2
HUMAN LEARNERS AND VIRTUAL HUMANS TOGETHER IN A 3D CVE

During the lecture, and the course in general, the virtual tutor will gradually "learn" about the existing skills, activities and possibly social connections of the students. For example, the tutor can register quiz results, the correctness of the answers to own posed questions and questions addressed to the tutor. The analysis of these data can reveal those parts of the curriculum that are not fully understood by individual students. A virtual tutor can also be aware of students' engagements in different activities. This is the case of online deliveries, virtual project presentations or even chatting to class mates during lectures. The analysis of the "buddy lists" structure and the participation patterns in joint projects/online deliveries will provide the tutor with some indications of the social structure in the learner community. In other words, the virtual tutor will acquire a certain "social awareness" of them. Using this knowledge, the tutor can then adjust the educational methods according to the individual needs, skills and learning style of the particular students.

During mutual encounters, the robot and the virtual tutor may have a connection "hidden" to human users. This connection is meant for the management of the robotic resources and the handling of its programmed behaviors, including the adjusting of the educational material, the refining of the teaching and interacting methods and the synchronization of lectures. The actors can exchange SA information about themselves, i.e. what resources each of them possesses, what other virtual agents/humans/robots they are in contact with (and thus what additional resources they can share and acquire) and what activities they are engaged into (e.g. the virtual tutor's lecturing plans). The virtual tutor can also provide the robot with the SA information that has been acquired about the students. This allows to individually adjust the robot's presentations and educational tasks that are given to the students, and vice versa. It is worth mentioning that with the current state of technology, the possibility for robots to acquire SA information about human users is significantly lower than the corresponding one for VHs.

In other educational scenarios robots can perform experiments or demonstrations, as it is in subjects of physics, chemistry or mechanics. The learning stimulus in these scenarios is more engaging and effective for students, who observe the transposed abstract concepts in reality rather than in a virtual environment. The robot acts therefore as a conceptual concretizer and induces a complete new perspective view of the conducted experiments. The dislocated students, that for different reasons do not have the opportunity to be present at the demonstrations, can benefit from following the "virtual" version while engaging in the learning process with the "local" students and the virtual tutors.

Though the practical implementation of such scenario could be quite complicated and costly under the existing technological means and constrains, it is important to illustrate some directions for future developments. Also, the above scenario case is suitable to illustrate how SA mechanisms, applicable to human users, can be extended to VHs and anthropomorphic robots.

EXTENDING SOCIAL AWARENESS MECHANISMS TO VIRTUAL HUMANS AND ROBOTS

Representation of learners in educational CVEs [5, 16] can be characterized in terms of *presence, embodiment and identity*. This kind of framework is examined in this section when applied to VHs and, to a certain extent, to anthropomorphic robots. Also, a comparison of the associated SA mechanisms is done, highlighting the possibilities for convergence and integration in educational situations. The focus is primarily set on how VH and anthropomorphic robots can convey SA information to human users. A throughout analysis on how these actors can convey SA information to each other or how to obtain corresponding information from human users (as already shortly mentioned in the previous section) is too demanding to fit in the scope of this paper and will be treated in subsequent works.

I. Virtual humans

Many examples in scientific literature [14, 21] show that VHs are fully capable of engaging in different types of social activities with other VHs or human users. Elaborating on the earlier classification [16], VHs are characterized in terms of *presence*, *embodiment* and *identity*, as discussed below:

Presence. Hindmarsh et al. [7] distinguish between *personal*, *social* and *environmental presence*. *Personal presence* for a human is defined as the feeling of being in a virtual world. Also a VH [21] has a certain perception of the virtual environment as a sum of different stimuli, which affects its cognitive system, behavior and actions. *Social and environmental presence,* in respect to VHs, is defined as the extent to which other beings in the real world and environment itself appear to exist and react to the VH and its actions [7]. In this context the sense of *environmental presence* can be supported by specifying the properties of the different subjects/objects and the rules according to which VHs can interact with them [21] (which means how a virtual tutor can write on a whiteboard and show pictures, and so on). The sense of *social presence* can be supported by providing responses (e.g. appropriate facial mimics and gestures) to the actions of human users [2] or other VHs (e.g. virtual teacher assistants), or registering the corresponding responses from other actors to the VH's presence and actions. This means that when a human (a student) is directing the gaze to the VH (virtual tutor), showing attention or requesting assistance [14] the system registers these variations and takes action. VHs can employ more explicit techniques, normally not available to human users, such as knowing and being able to compute the exact position of the users, the relations between them and the surrounding objects etc [14]. In the mentioned scenario, the VHs would be capable of e.g. monitoring which users are engaged in conversations and joint activities with each other.

Embodiment. An important part of the communication between people in the physical world is body language, like gestures, body postures, facial expressions, direction of gaze [17], as well as clothing and make-up. Therefore, as among humans, the embodiment of VHs can be supported by the following: *choice of avatars*, *body languages*, *navigational and observational possibilities* [5]. *Avatars* can represent the identity of VHs, their status, accessibility and role [17]. One explanatory example would be the case of a virtual tutor and a virtual patient in a medicine class. Whether avatars provide photographic resemblance of a concrete human (e.g. a concrete university professor) or a realistic-like or a schematic appearance of a human, is important for human users' perception and appreciation of the VHs, influencing user behavior towards them and the extent of experienced co-presence with the VHs [2]. Like humans, VHs can exhibit a number of gestures and movements such as turning around to the communication partners and waving. Especially important in this context is head movements and facial features, as it is linked to personality expressions and natural conversation. The facial features are controlled by two parameters, mood (angry, happy) and attention (direction of gaze) [14]. VHs have different navigational possibilities, like *walk*, *fly* and *teleport*. In the context described in this paper the most important aspect of the VH navigation is the one visible to the human users, which would also allow aiding users' navigation by showing the way through paths or excursions.. The sensorial possibilities of VHs can be easily extended by "allowing" additional sensors (e.g. tracing the activities of users in the environment) or violating physical laws by extending the normal hearing and visibility range [21]. This would permit to simplify the process of acquisition of SA information by the virtual tutor, as mentioned in the scenario.

Identity. For human users the identity is often tied to a name/nick or a chosen avatar. The identity is primarily expressed in terms of *communication history* (including both verbal and non-verbal communication), *associated social reputation* [8] and *created artifacts*. The same can be applied to VHs as well, though modeling VH's communication requires the modeling of its beliefs, desires and intentions [14] and ways of coping. One of the most relevant personality models is the *five-factor model* [11], based on the *openness*, *conscientiousness*, *extraversion*, *agreeableness* and *neuroticism*. When acting in a virtual environment, VHs can have social relationships with both human users (e.g. tutor-student relationship) or with other VHs (as it happens between virtual tutors and their virtual assistants). Therefore, the social dependencies and social power (place in the hierarchy) in these situations are important [4, 13]. A VH can also have a social reputation, e.g. being known as "knowledgeable" in a certain field, such as a teacher or expert. In many CVEs the identity is tightly coupled to the artifacts created by human users or VHs, such as buildings and educational objects.

II. Robots

For technological reasons, the present state of robotics provides smaller possibilities for advanced interactions compared to VHs. For example, it is difficult to implement advanced mimics and manipulate embodiments, just to mention a few. This puts a certain limitation on the corresponding SA mechanisms. Existing research on awareness between humans and robots focuses primarily more on "workspace" related awareness, considering issues such as robot's activities, status, location and surroundings [6]. Though these issues are partly considered here, the main focus is set on the social and educational aspects, considering some examples of the emerging technologies, and showing how the basics of SA mechanisms could be supported.

A recent technological development in the sector of robotics supporting e-learning and behaviorist studies is Robo-eLC [10] (Fig. 1), a robot that embeds state of the art technology with a Multimodal Interface (MI). MI uses hypermedia with a combination of learning technologies and robotics into an interactive learning appliance for affecting users' learning attitudes [12]. The scope of the MI is to simplify the comprehension and acquisition of complex data and aid users in grasping ideas and concepts related to unfamiliar situations. In this case, the MI consists of visual interface, the audio system and the motion system. The integration of multimodal elements in the robotic functions has also guaranteed the perception in the users of dealing with an "almost" living being (as some users stated after using the Robo-eLC). The fact that the robot can "imitate" some human behaving attitudes, such as talking to give advices, moving to attract attention and respond to users' touch (via the touch screen) constitute an anthropomorphic robotic behavior.

As with the human users and the VHs, robots with similar features to the ones of Robo-eLC are characterized along the dimensions of *presence, embodiment and identity*:

Presence. People and the environment react to the robot functions and a mutual interaction is started. The robot uses sensors to perceive the environment and models to identify, via intelligent system (an application of artificial intelligence), the surrounding objects, distinguishing between still object and mobile ones (i.e. people or other robots). The robot has communication skills, based on its noticeable appearance and its capacity to talk and initiate a sort of conversation. A class of robots that do properly express the concept of presence is *mobile robots* that operate in populated environments. For this reason robots need to determine the positions of the humans in their surrounding and therefore track multiple moving objects, as is the case of a group of students surrounding the robot and interacting with it. Usually these robots use sensors and a motion model of the objects to be tracked [19].

Embodiment. As in the case of VHs, the embodiment of a robot can be characterized in terms of *appearance*, *body language*, *observational and navigational possibilities*. The robot needs to express in its appearance the quality and functionality it is meant for. The programmed behavior of the robot must convey the concept of its intended purposes, therefore the robot shall move, talk, interact and even change appearance according such purposes or scopes. Robots must be capable of imitating to a certain degree a body language, via gestures and mimics, such as the human-looking robot in our example, to *embody* a representative from a developing country. One class of robots that better embed these characteristics is the biorobots that can simulate behaviors of living beings and adapt themselves (camouflage) to a given framework. Recently, some humanoid robots, based on similar principles, have been designed to investigate models of social development [22]. Some robots, especially mobile ones, require skills in defining not only their environment but also in choosing a correct pattern to reach a chosen destination. A conscience of own position and direction is needed to allow any efficient spatial motion. Some robots are even capable of a certain degree of independency (*autonomous robots*), acquiring navigation routines to support their specific task execution and effective action planning. These kinds of robots are capable of learning structured symbolic navigation plans [3]. Robots can also have different observational capabilities observing the environment using sensors. They can transform all input data via sophisticated algorithms that allow the recognition of defined models. Typically these are the *pervasive robots* that exhibit complex behaviors.

Identity. A robot should be capable of carrying a personalized character, with specific distinguishable behaviors, which makes it recognizable in a community of humans and other robots. This is possible thanks to a profiling feature that is dependent on users' history or the robot's experiences. Such profiles (packs of memory) are stored as metadata in the database of the robot, waiting for activation and decryption to create, via the use of given algorithms, of new behaviors. Such feature is under development in the new prototype of the Robo-eLC [9]. The identity is primarily expressed through communication and in some cases via created artifacts, such as records of interactions with users [9].

III. Virtual humans and robots in a learning community: social awareness mechanisms

Based on the preceding discussion, it can be shown how the SA mechanisms, originally discussed for humans, can be extended to VHs and anthropomorphic robots in an educational context. As mentioned before, the focus is mostly set on how VHs and robots provide awareness of their social situation to the humans.

The resources of both VH and robots can be primarily indicated through the choice of the embodiment as the variable appearance can express a specific skill/expertise and visually communicate ideas and concepts. Therefore, a properly dressed robot can be perceived as a knowledgeable expert on developing countries as well as a virtual tutor looking like a typical "professor" in a business suit and glasses signalizes expertise in theoretical matters. The resources can also be expressed through identity (e.g. when a robot or a VH explicitly communicates and shares its knowledge in certain areas). Created artifacts (e.g. quality of a created educational demonstrations or an interaction record) revealing how well a VH or a robot can answer questions in a certain field can also provide awareness of VH's or robot's skills and knowledge. Also the presence of a VH or a robot in a certain place (e.g. a chemistry lab) may indicate what kind of help it may provide.

The sense of presence, real-time communication and embodiment can provide awareness of *social network*. It can be obtained by observing what VHs or robots are around (e.g. overview of the avatars/physical robots) and to whom they are talking to (grouping of avatars/users), eventually designating whether they are busy helping other users. Also, the gestures, sounds and mimics made by the VHs/robots and the direction of gaze (embodiment) can indicate their involvement in a conversation with a certain partner and particular topic and attract the attention of the users. The appearance/choice of avatar component of embodiment may signal the role and place in the social hierarchy, e.g. a virtual tutor/doctor vs. a virtual patient. Also identity, expressed through e.g. commands given from the virtual tutor to the robot, can provide awareness of the social power relations, e.g. who is the superior part or "master" [18] (in this case the virtual tutor). Long-term awareness mechanisms in this context include expression of social belonging through records of communication/interactions and created artifacts, as it is the case for records showing with whom a VH or robot has been cooperating or who owns the areas where the VH builds its constructions. The recorded or logged communication incidents between robots and VHs can be mediated by different means (including infrared signals, GSM, web, etc).

The awareness of *activities* can be achieved through real-time observation of conversations, either chat or audio, and movements of corresponding avatars/robots. For example one can see what VHs are gathered in a virtual meeting room (sense of presence and embodiment) and follow their communication and movements while they talk to and help a human user with various learning tasks. Similarly, a robot moving around, interacting with students and executing commands [6] can provide awareness on what activities it is engaged in a specific moment. A robot or a VH can also explicitly communicate the activities that are being performed or can be performed to the user, for example by providing a menu on a touch screen, in chat or via audio channels. Communication records may also provide a clue of past activities, such as lecturing and guidance sessions with the students. Traces of activities can be also found in artifacts created by a VH, as it is in an experiment demonstration that the VH has built. Another example of this is the records of user interactions occurred in the Robo-eLC test case [9].

DISCUSSION

VHs and anthropomorphic robotic appliances can be integrated into one system, supporting and participating in a learning community of human students and teachers.

Generally, the VHs can perform a number of tasks in an education context. Some examples are:

- Helping the users with the reshaping of the virtual environment according to their current learning and social needs, e.g. creation of a customized virtual chemistry lab.
- Providing general guidance to the learners and performing administrative tasks, as giving information about the campus to new students, managing a student's course assignments, arranging social activities etc.
- Performing tutor-related tasks, such as giving curriculum-related consultations, evaluating the progression of the learners or giving educational demonstrations.

Similarly, anthropomorphic robotic appliances can support learning communities in a number of ways:

- Transforming and adopting an "*anthropogyzation*" of the learning contents that the robot has to communicate, issuing a cultural strong link between people's cultural background to be learned and the regional background (way to dress, to speak, to act, to communicate, etc).
- Becoming a human-like friend in guiding learners, which can be related to school tutoring or monitoring and surveillance of impaired and handicapped children.
- Working with/in dangerous techniques/operations (e.g. handling explosive material) or moving in dangerous environments. The robotic use of sensors and the simulation of the conducted experiences allow students to learn from real practice without running personal risks.
- Detecting cues about the current social situation. The combination of human actions detection, sound and facial analysis can determine with a high accuracy the psychological condition of an individual.

From the above discussion it can be identified a number of areas where the two approaches can be merged, given some expected technological developments that the current trends foretell, as summarized in the following cases:

- The use of robotic appliances might be especially relevant in educational situations where VHs are not fully sufficient. A fully educational experience requires a direct contact, the possibility to touch and feel and direct extraction of social cues, as for example in the case of a physics experiment or a simulated cultural experience.
- The combination of the two approaches is primarily relevant in a partly distant educational situation where some of the students are co-located with the robot(s) and interact with it directly, while others due to different reasons do not have this possibility and therefore may benefit from the specifically designed virtual environment where such interaction can be mediated. Such an environment could also be beneficial for the co-located students as they get the possibility for collaboration with distant peers and receiving assistance from virtual tutors.
- A promising area in this context, as also mentioned in [20], is the usage of robots in educational situations associated with health risks or additional costs, such as demonstration of experiments in a radioactive environment. In such a case, students may interact with the robot's representation in the virtual environment, under the guidance of human or virtual tutors.

The preceding discussion allows to make some preliminary comparisons of the possibilities of both VHs and anthropomorphic robots to support SA. Obviously, VHs have at the moment more varied possibilities for SA support. The reason is clearly the lower cost and more advanced technological possibilities for designing VHs in virtual environments. However, the anthropomorphic robots have a number of advantages in this context, at least potentially. They may exhibit a higher degree of *presence* as they can be perceived more directly by human users, touched and thus provide a stronger and more natural social experience. The same applies to the embodiment dimension: robots can in many cases have a more realistic and socially appealing embodiment, such as a culturally dressed representative, provoking a specter of emotions (e.g. compassion) [9]. A robot may have also a more permanent and recognizable identity as it is connected to the concrete physical instance and unchangeable appearance.

At the same time, we can see many similar features in terms of SA mechanisms that could be supported by VHs and anthropomorphic robots. The existing differences can, in many cases, function as complimentary to each other, for example the flexibility of the VHs versus the "realism" of the anthropomorphic robots. This, together with possible educational gains, as discussed above, provides a motivation for further exploration of possibilities for integration of VHs and robots in different educational situations.

CONCLUSIONS AND FURTHER WORK

In this paper, the authors have provided some directions and examples for how human learners, virtual humans and anthropomorphic robots could work together in different educational situations. It has been also discussed the social awareness mechanisms in such community, especially the possibility to extend the mechanisms applicable to human learners to virtual humans and robots. The authors are aware of the difficulties associated with the realization of the proposed scenarios with the current level of technology. However, the idea of combining all of the 3 actors (humans, VHs and robots) into one 3D virtual system is quite innovative as only one implementation case is known of this kind [20].

In this context, the contribution of this paper is more of a theoretical nature. The authors believe that this area has an extensive potential, especially in a distant education context and needs further exploration. Therefore, it is necessary to provide a broader theoretical framework for design and analysis of social interactions between all of the 3 actors in the learning communities in 3D CVEs. This paper attempts to set a first step in this direction. Further steps in this work may therefore include the provision of a set of requirements for the educational environments incorporating all of the 3 types of actors. Subsequent steps will require a design according to the requirements and implementation of a corresponding prototype with the following empirical evaluation. In addition, the associated SA mechanisms need to be explored further, including the issue of how robots and virtual humans perceive the social situation in the community they are a part of.

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Publications PAPER V

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5

Fund Raising Systems using Robots (Architecture and Behavior Study)

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Abstract – **In this article we present an interactive automated robot called RoboBeggar that has fund raising capabilities. The system consists of a human-like multimodal robotic unit controlled by a computer. A stand with a touch screen display and a bank card reader provides access to the e-learning and e-commerce applications of the robot. The primary use for the existing robotic system is to collect donations for charity activities and to transfer charity related knowledge to the users of the robot. The robot can be placed in major public places. In the test case presented in this article, its location was a church during the Christmas festivities of 2004. The control system of the robot is a software built upon a Java framework in a way that it can be used for a variety of applications where human interaction is required (i.e. shopping, listing adviser, consultancy, etc). This article describes the architecture of the robotic system, the solution chosen for the simple management of its complex interface modules and its feasibility for providing insightful data about human interaction. In this article we also discuss possible user scenarios and future perspectives.**

Index Terms – Fund Raising, Automation Management, Interactive Behavior, RoboBeggar.

I. Introduction

Robotics is a research field that is actively being developed also in education and service related fields. Some of the primary interests of robotics researchers are focused in the following areas: *embedded system design* and *artificial intelligence* [1,2].

From the technical point of view the *begging robot* (named *RoboBeggar*) is a complex combination of software and hardware devices. (See Fig.1 for a picture of the robot). The main difference between a traditional technical appliance meant for money collection and the RoboBeggar is in RoboBeggar's awareness of the situation. The robot reacts to the behavior of the eventual user and behaves according its role in the location environment, stimulating the interests of other potential users that might be in its proximity. In response to user actions, the robot software controls several peripheral devices that result in movement of robot parts, playing appropriate sounds, feeding of specific e-learning modules, etc. The reactions of the robot must be quick and adequate to the situation. It is well known that human interaction with robots can produce novel experiences and that for this to happen it is also required that human and robot can perceive each other [3]. In this article we present a possible solution for concretizing a HRI for boosting the perception and the cognitive processes.

The robots must perform some intelligent actions. These are related to a pre-defined idle condition in which the robot calls and attracts the attention of passersby. As soon as a user starts to interact with the robot via the touch screen, the robot uses some of its modules to provide the user with the information the user wants. Meanwhile the robot takes into account the behavior of the user and gives suggestions on specific matters or encourages the user to proceed in the use of the learning modules. Elements of cognitive science have been taken into account to track, stimulate and, where possible, to foresee the learning behavior of the users [4]. This robotic *intelligence* is the feature that makes the using the robot attractive to the user.

The software controlling the robot is constructed in such a way that easily allows for addition or modification of hardware. It is also possible to modify the robot behavior scheme (its *intelligence* part) in an easy and straightforward way. This specific part of the software, which is continuously under improvement, is intended to make use of metadata and tracking information collected for each user so that the robot can recognize the specific user and, therefore, deal with the user in a personalized way.

Fig. 1. The fund raising robot (the RoboBeggar)

One of the relevant aspects of the design of the management interface is that the needs of the laypeople that will probably operate the robot have been taken into account. The *operator* of the robot does not need to posses deep knowledge or understanding of the entire robot structure in order to maintain it. Indeed, with the interface that has been developed, the operator is able to quickly change the sequence of the robot's actions and most of the other features related to the robot's behavior. The result is that the robot operator can maintain the robot in an easy, quick and intuitive way that enables the creation of new e-learning modules and, consequently, allow the operator to specify new robotic behaviors [5].

II. System Description

A. *RoboBeggar interaction and behavior*

In idle mode, the robot vocally invites passersby, with randomly chosen messages, to approach and start using the system. Approaching the robot, users find the touch screen has a rotating, 3D world-globe screensaver on which an invitation to begin interaction is displayed. A touch from a user activates the robot, which responds by thanking the users for accepting the offer for interaction. A window is then presented where the user has the opportunity to register with a personal code or to continue anonymously. In the case that the user had already created a personal code in a previous session, the insertion of the same code allows the personalization of the user profile, whish is stored in the robot. Next to the access-code window, the robot presents the first e-learning module (*e-module*) where basic information and links to other more detailed e-modules and resources are given. A domain-restricted internet access is also present in this first general e-module that gives the user the opportunity to explore, in more detail, the arguments for giving to charities and to collect information on charitable giving in general. Browsing is time-limited. The robot keeps talking and encouraging users through the interaction process and in users' search for information. Its limb and head move according the situation (i.e., specific e-module, expired time from last user interaction, etc.) to simulate human-like interaction [4]. The user, when going through a detailed e-module, can choose to make a donation at anytime. A backward function, which allows the user to move back and forth between the e-modules, is available in every window. After choosing to donate, the user is presented with another window, the donation window, where pictures (*value pictures*) of 1 and 2 EURO coins and 5, 10, 20, 50 and 100 EURO banknotes are preset. The donation window reminds users of the specific donation target. After a user touches one of the value pictures, the robot brings up a confirmation window where the user is reminded of the specific donation (i.e. the amount of money and charitable destination) and asked to pass the bankcard in the bankcard reader slot. While the user passes the bankcard through the bankcard slot, the robot reads the security code and transmits money transfer information to the bank via a secured GSM channel. After this transaction, a thank-you screen appears and has a summary of the information related to the donation. A receipt of the donation is printed that indicates the time, the chronological donation number, the occasion, the purpose of the donation, and the amount of given money. A short while after the thank-you window appears, the robot switches into idle mode and the world-globe screensaver reappears.

When the robot is in interaction mode, it records the time that elapses between each response of the user. The robot has a predefined time to act or react to users' activity or inactivity. In case too much time has elapsed in one e-module phase, the robot first warns that time will shortly expire and then, soon afterwards, switches to idle if no response from the user is received. Hence the robot talks and moves based on users' responses or lack of responses. The overall aim of the robot is to give to the user a sense of collaboration in the process of charitable giving and to provide the cognitive aura to stimulate users' actions. This cognitive aura is discussed and sustained in the article "Robo-eLC: A Robotic Adaptive Learning Appliance" presented at the International Conference on Cognition and Exploratory Learning in Digital Age, CELDA, 2004. [4]

All rules that dictate the specific actions of the robot are set by the robot manager or by the operator. The rules regulate when and in what circumstances any specific robotic action happens. These actions include the movements of the head and the right limb, the use of vocal messages, the flow of the touch screen windows, the use and breadth of Internet access, the use of the bankcard reader and the transmission of the secured data, the printing of the receipt and finally the time-counting between each possible action.

All results obtained show that the behavior of the robot produces a positive effect. In general, users feel excited and positively motivated in browsing the e-modules and acquiring information. Most adult users made a donation, which resulted more consistent when compared to similar and local collecting situations.

B. *System building approach*

One approach to building the robot is to build it as an *embedded system*. The Embedded System is a combination of computer hardware and software, with the addition of other mechanical parts, designed to perform a dedicated function [1]. In some cases, embedded systems are part of a larger system or product, as is the case of an anti-lock braking system in a car. RoboBeggar is a fully functional appliance; it has all of the needed control systems and adaptive modules already within it. The intelligent core controls and arranges the movement of the head and the right arm, the vocal functions, the interaction with the user via the touch screen, the Internet connection and its use, the bankcard reader and its secure data transmission to the banks. The intelligent core will soon allow the RoboBeggar to do its own data analysis and make autonomous decisions concerning what action to take in a given situation.

In our case we aim at constructing an easily extendable model that allows adding new functions without significant change to the existing code. This can be achieved by using an design method in which the system is modeled as a collection of cooperating agents, (i.e., objects.) The individual objects are treated as instances of definitive classes within a certain class hierarchy. There are four design stages: (1) *identify the classes and objects*, (2) *identify their semantics*, (3) *identify their relationships and specify class and object interfaces* and, finally, (4) *implement the design* [6]. To extend the system some external modules should be added or otherwise replace some of the existing ones.

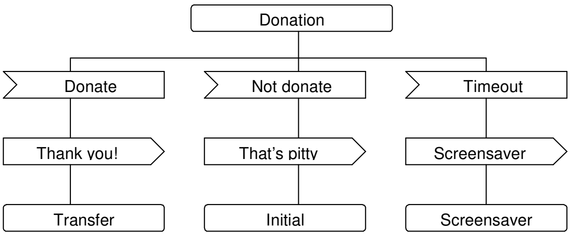

Fig. 2. The rules definition for the donation choice state.

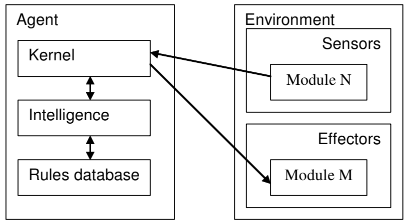

Fig. 3. RoboBeggar system architecture.

Another requirement for the system is that several actions should happen simultaneously. Thus each module must have its own execution thread [9].

C. *Self-management of the robot*

The robot has an intelligent behavior, which means that a set of rules define the robot's behavior. The robot is capable of interacting with the users in a way that encourages appropriate learning behaviors and stimulates their cognitive activities [4]. The robot manages itself according to its set of rules, which constitute its "brain". For flexibility reasons, the rules are stored in an XML file, which is loaded during execution time. The robot also uses frame-based logic. It has several states, and for each state there is a set of rules. When some event happens, the robot chooses the response action according to the specific state, event and rule. An example of rule definition used in the robot is shown in Fig. 2.

D. *System architecture*

The system consists of several main components. The system class-diagram is outlined in Fig. 4. Each system components is an object, which runs on its own execution thread. The main objects are instances of the classes that inherit the *RoboThread* class [8], which in turn describes common thread behavior. Objects can interact by sending each other messages. The central object of the system is a *Kernel*, which is an instance of the *RoboKernel* class. It dispatches all messages in the system.

For managing the system, there is an *intelligence module*. After receiving message requests, the *Kernel* checks with the intelligence module for the proper order, the intelligence module in turn looks for the available rule and after retrieving it, transmits the data to the kernel that sends the command to the appropriate component of the robot (e.g., to the learning module component, voice component, movement component, etc.) (See Fig.3 and Fig.7). This system avoids many problems related to the handling of multiple commands that caused hang-over situations in previous prototypes. In those situations the robot used to stall the audio components remaining mute or stopped to move for short periods.

This architecture brings flexibility into the system. If anyone wants to change the behavior of the system, the only module to change is the intelligence module. If anyone wants to add any hardware to the system that person should develop a module responsible for the new hardware and then add some commands or events to the intelligence module.

The system implementation language is Java. It has been chosen because its portability and because it is appropriate for rapid development requirements. The system could be easily ported to various platforms, such as Win32, Unix [7], etc.

E. *Message passing*

The system is driven by messages. Each module can initiate some set of actions by sending a message to other modules. Usually message sending is caused by some events (e.g., the user has pressed a certain button or the card reading has succeeded.) Messages are sent to some certain module, and the sender specifies the receiver of the message before sending. Receivers are main modules. Main modules are addressed by string identifiers. The string identifiers simplify the use of the system for beginners.

Each module has its own message queue. The selected modules do not process all the messages they have received; they process only the last one. Otherwise, the robot would pronounce, for example, phrases at the wrong time. For this reason, there is a member-variable controlling this behavior.

Message handling is done in a separate thread. This allows the robot to speak, move and change the display picture simultaneously.

F. *The Kernel module*

The main module of the system is the kernel module. In spite of its importance, its implementation is very simple. The task of the kernel module is to receive event from peripheral devices modules, to request information about actions and to transmit these commands from the intelligence module to the peripheral devices modules. See Fig 5 and Fig 6.

The behavior scheme of other objects is quite similar. The only difference is that they do not request any information from the intelligence module. They interpret commands and handle them by themselves.

G. *Intelligence*

The current behavior of the robot can be described as a reflex agent [2], where the user action (as environment main source) causes a robotic response based on its rules and metadata. This behavior is graphically described in Fig 7.

The current implementation of the intelligence module uses a XML rules database file. This file is loaded during

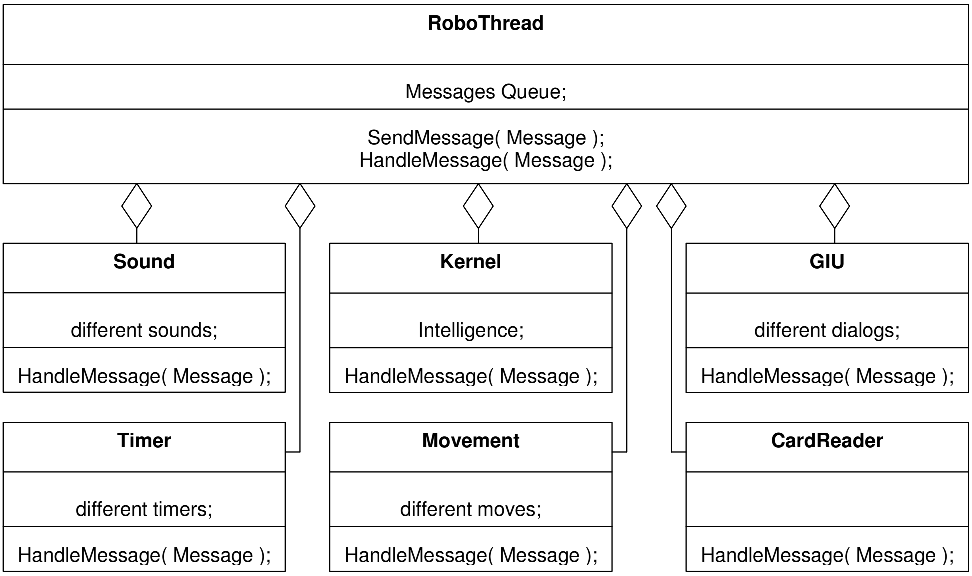

Fig. 4. The fragment of the system class diagram.

system startup, so the operator can change the robot's behavior according to the operator's remarks and wishes. However, to apply changes the operator needs to restart the system.

H. Actions tracking

The robot also contains the possibility for actions tracking. This feature can be used for software debugging, for intelligence improvement and for the statistical analysis of users' behavior.

Every time kernel receives a message or sends a command, it sends a message about this event to the logging module. The logging module constructs a record and sends this record to a database. The record contains a timestamp, a message originator, a message receiver and all message parameters.

A special tool was developed to comfortable exam the database log. Operators can specify which time, which message originators, which message receivers and which sessions they are interested in examining.

III. TESTING AND RESULTS

A. About the Users

The working system of the RoboBeggar has been recently tested in the entrance hall of a church (Church of Noljakka, Joensuu, Finland) where people could easily see and hear the robotic appliance. The robot was used during the festivities of Christmas 2004, guaranteeing enough potential users. At four seasonal events, the designers of the system supervised and kept written records of the individual (user of the robot) and group (observers of robotic actions) behavior in relation to the robot. The amount of people assembling during the four events was between 80 and 150. Consequent analysis of the behaviors of the people and their actions when approaching the robot were conducted. Forms containing various multi-choice questions and qualitative answers were submitted to the users of the robot. Such feedbacks were collected to conduct a qualitative-quantitative analysis. About 20 forms were collected.

```
void RoboKernel.handleMessage( Message msg )
{
  Command response[];
  Response = intelligence.getResponse(msg);
  for (int i in response)
  {
    send(response[i].receiver,
        response[i].command);
  }
}
```

Fig. 5 The scheme of the *handleMessage* method of the Kernel class

From the feedbacks and the observations it is clear that some level of technophobia affected many people when dealing with new and sophisticated appliances like the RoboBeggar. Nevertheless some people that originally were perplexed by the robot got quickly acquainted to it after starting to use it. In some cases in this environment (and in previous evaluations too), the users seemed to experience some sort of enthusiasm and joy after having successfully used the appliance. It is interesting to note that teenagers and youngsters have shown greater interest in exploring the features of RoboBeggar than adults.

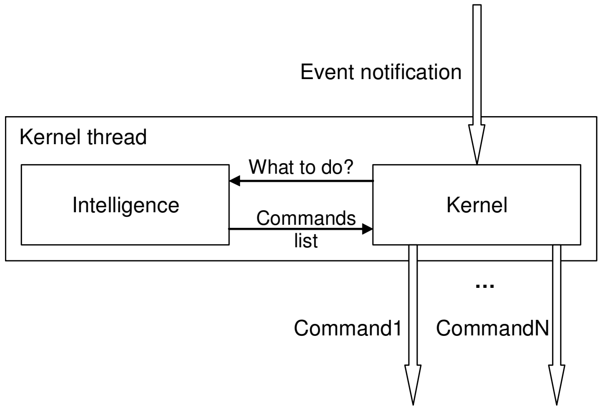

Fig. 6. The kernel behavior scheme

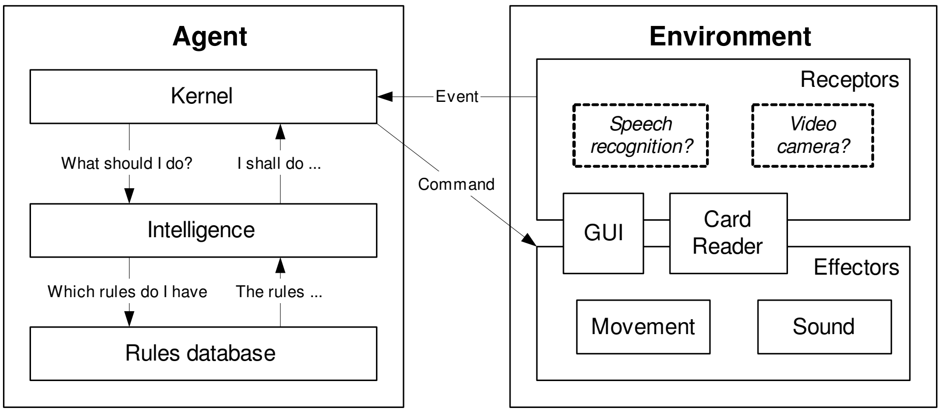

Fig. 7. The robot as an agent

Users have confirmed that the clear instructions found in the robot and the incentives given by the system quickly led to a donation. The quality of the e-modules is fundamental for satisfactory interaction and users have always expressed wishes that the robot would be improved. The robot voice interaction has proven to be relevant for some, but not all, of the users. Many users would like to use the robot in a private or semi-private environment, probably because of the nature of charity fund raising.

In our overall assessment, we can say that the RoboBeggar is a functional fundraising appliance and its capacities do constitute a sound platform that, nevertheless, needs to be improved based on users' feedback.

B. About the Operator

On this test occasion, the RoboBeggar modules had been organized and prepared by a non-expert operator. One of the partners accepted to design the e-modules and provide the sounds needed to give voice to the robot. After some initial hesitation and some corrections to the robot management interface, the work started to gain momentum. Only few of the provided elements had to be reworked by the designer of the system and fit back into the robot's system.

The results of the RoboBeggar interface were not completely satisfactory, due to the fact that the chosen designer had low graphic and artistic skills. This, obviously, was reflected in the perception of the users. Our conclusions about the requirements for a non expert to be eligible as *perfect* RoboBeggar operator, and hence to design the e-modules, are that the operator should (a) have some artistic skills (i.e., have a basic artistic sense for color distribution, spatial picture positioning, choice of image dimensions, etc.), (b) should have some basic understanding of image editing (i.e., how to change file formats and dimensions, how to use filtering, etc.), (c) should have some concept of html editing (i.e.., how to create links in the main e-module for the Internet domain and create some html pages on Internet, etc.) and (d) should be capable of synthesizing large amount of data in a few sentences or figures. Given all of this and enough time to get acquainted with the tutoring interface, the operator would be capable of creating or adapting the e-modules to any need or circumstances. If considering work situations where natural skills are scarce, it is clear that the combination of the above mentioned requirements should be searched and found in two or three individuals instead than in a single candidate. In addition, it seems that the *artistic skills* are more dominant than the technical ones in an operator that would create a successful interfaces.

C. Overall results

According to the tests conducted, we can say that the architecture of the robot is quite successful – it was quite easy to modify the system for the current tasks and needs. There was also some kind of stress-testing performed by children, which the robot passed successfully.

On the other hand, there are some areas for improvement in the current system:

- It was unstable because of intensive memory operation and the usage of Windows 98 operational system. For various reasons it was not possible to use a newer OS, even though the hardware and software could cope and benefit with W2K or higher. To manage and avoid this trouble in the future it will used the Linux operational system.
- The touch-screen of the user interface should be improved. The buttons should be larger and the distance between buttons should also be increased. Tutors will have to take into account this information.
- The current intelligence works satisfactory but it would be advantageous to try other non-static types of intelligence, which could allow, for example, supervised learning.

IV. CONCLUSION

In this phase of improvement of the RoboBeggar, an intelligent system has been used in a XML rules database file, which provided the rules needed for robotic management of components. During the test, it has been proved that this choice has practically eliminated all functional bugs related to the handling of commands. In addition, the robot could be managed by a non expert and its behavior was easily redefined at will. The administrator of the robot could manage, have access to the modules of the robot, modify the visual and aural interface and the physical behavior of the robot with no difficulties.

We expect to have the complete and full management of the robotic parts (except for the bankcard reader) plus the external printer in an easy user interface. Intelligence will also be implemented in terms of the capacity of the robot to "remember" individual users. The problem related to the loading of any new set of rules, which happens during the system start-up, will be modified and separate from it.

Further on we expect to implement both a voice recognition system and a motion recognition system so that the robot will be able to "look" at the user and follow the movements of the user. Intelligent tissues will be used to add expressivity to the face and provide a more realist interaction between the user and the robot.

The next innovation feature for the robot is the self-management that the robot will have. Obviously, as described in the article, the rules will always set the limits for the robotic behavior. However, future self-management will include the ability to choose among a variety of behaviors and keep the best one according a specific user's behavior. The combination of mastering the vocal modules, the movements and the interface of e-learning modules will grant the robot a wide spectrum of possible interaction tools that will positively affect the quality of human-robot interaction.

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ROBO-ELC: A ROBOTIC ADAPTIVE LEARNING APPLIANCE

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ABSTRACT

This article describes a robotic adaptive learning appliance called Robo-eLC. The appliance is the result of a multidisciplinary approach which combines e-Learning and e-Commerce elements and is capable of interaction with its users via audio-visual communication. The robot integrates elements of education, sociology, robotics, cognitive science, and computer science and takes into account human behaviors and cognitive processes.
Robo-eLC is designed to accelerate users' learning processes and encourage users' positive interactions with its multimodal interface. The operability of Robo-eLC as a learning appliance was tested during a fund raising event in 2003. The robot acted as a learning stimulus for the users while they operated through its system to donate money for three specific developing countries. Through the process that led them to donate money, users acquired information and knowledge in fields of human aid, geography, economy, anthropology, ethics, and culture. Learning modules were used to sustain users' learning. The users' feedback showed that the robot had been positively influencing the learning behavior of the people and that it had successfully aided users in the comprehension of a number of complex concepts.

KEYWORDS

Cognition, Education, Behavior, Multimodal Interface.

1. INTRODUCTION

This paper gives an overview of a multidisciplinary project called Robo-eLC and highlights the potential impact that robotic multimodal interfaces can have on the learning behavior of users. The fact that the robot has been designed for a combined application of e-learning and e-commerce (La Russa, 2003) and that its multimodal interface interacts with users to increase their quality and level of cognitive processes shows how great the result of combining disciplines can be. In the case of Robo-eLC, we have implemented elements of education, sociology, engineering, cognitive science, and computer science.

As it is nowadays recognized, the imitation of the behaviors and emotions of others is a fundamentally human activity - perhaps even, *the basis* of human activity. Damasio (1994) states that social systems may not be reduced into the biological systems; however, biological systems are strongly related to the bio-logical (neural) systems which are based on personal level (level 2) brain processes (level 1). *Imitation and imagination based on emotional judgments* are (according to Damasio, 1994) the subject level processes needed to understand and assess other's acts - especially those acts related to the assessor. In socio-anthropology, the theories of Rene Girard (1977) have played an important role over the last twenty years. These theories can be seen as a transition from biological to cultural interpretations of behavior. Although the theories concentrate on the anthropological reasons for myth and violence, their essence can be applied to learning situations under the socio-constructivist paradigm.

Furthermore, studies, such as Kistmann (1999) and Huang (1995), have analyzed the physical and abstract elements that influence the reasoning processes, investigated how these processes can be influenced, or determined how persuasion can interfere with the reasoning process itself,. It was found that the cognitive element of users must be taken into account when considering the learning and behavioral impact that a system is expected to produce. Problems arise when users interact with systems that provide a high and intense level of data flow. These kinds of knowledge power-tools have the potential to enrich the know-how of the users, given that users can cognitively cope with the rate of information flow.

The robotic project described in this article aimed at analyzing and broadening the use of ICT as means of learning in concrete appliances. Learning elements had to be taken into account to sustain users' cognition and to create a multimodal interface that complemented users' perception needs. A combination of constructivist theories (Papert, 1993; Chee, 1997) with cognitive processes and hypermedia interfaces gave form to the "Learning Multimodal Interface" (Vo et al, 1995) of the Robo-eLC.

2. COGNITIVE ISSUES

Before going on to present the Robo-eLC, let us take a brief look at some cognitive issues.

2.1 The Comparison between a Human Mind and a Robot's Inner World

The comparison between a human being's mental representation [of a certain portion of the world] and a robot's inner representation [of the same portion of the world] involves the concept of Intentionality. According to John Searle (1983), the difference between mental and physical representations can be expressed by the distinction between intrinsic and derived forms of Intentionality. Searle describes this difference as follows:

> Since sentences - the sounds that come out of one's mouth or the marks that one makes on paper - are, considered in one way, just objects in the world like any other objects, their capacity to represent is not intrinsic but is derived from the Intentionality of the mind. The Intentionality of mental states, on the other hand, is not derived from some more prior forms of Intentionality but is intrinsic to the states themselves. An agent uses a sentence to make a statement or ask a question, but he does not in that way use his beliefs and desires, he simply has them. A sentence is a syntactical object on which representational capacities are imposed: beliefs and desires and other Intentional states are not, as such, syntactical objects (though they may be and usually are expressed in sentences), and their representational capacities are not imposed but intrinsic. (1983: vii-viii)

When we speak about physical representation, we usually mean something represented on the paper, or on the screen, or somewhere where we can see it or touch it. By mental representation we mean something which can be "seen" or "touched" only by "the inner eye" or "intuition".

In the case of a robot, the model of the operational environment represented in the information system built into the robot is a syntactic object; the Intentionality of which is derived from the corresponding mental representation of the model designer. Only if the model corresponds accurately enough to the mental representation of the person communicating with the robot, then it is possible for that person to form a consistent picture of the operational environment and of the processes going on in it; i.e., the person is able to conceive the interaction with the robot and is able to learn new things on the basis of the mental representation corresponding to the mental representation of the model designer.

2.2 Conceptual Models and Sub-Models

There is much conceptual inaccuracy in information-modeling terminology. This especially concerns "conceptual schema", the ontological status of which has not been properly explicated by researchers. In other words, it is often difficult to find out whether one means by a "conceptual schema" a transcendental schema, a mental representation, or a physical representation. In addition, most researchers do not discuss the problem of conceptual schemata (as non-physical entities) as shared by different individuals. Donald Davidson expresses the problem as follows:

> Conceptual schemes, we are told, are ways of organizing experience; they are systems of categories that give form to the data of sensation; they are points of view from which individuals, cultures, or periods survey the passing scene. There may be no translating from one scheme to another, in which case the beliefs, desires, hopes, and bits of knowledge that characterize one person have no true counterparts for the subscriber to another scheme. Reality itself is relative to a scheme: what counts as real in one system may not in another.

The relations between different representations involving modeling activities form the basis for any framework within which conceptual schemata are to be constructed. However, some of the representations may be such that they cannot be captured by some other representation. This is also the reason why it is not necessary to take into account all the possible representations involving an application area. (1985, 129)

By what means is a "mental representation" (as Peirce conceives) or symbol (as Vygotski) directed to something (or, "refer" to something)? The answer is "By some conceptual sub-model".

According to Peirce (1931-60), both sensations and concepts are mental representations. A similar idea has been held by Vygotski (1978a, 1978b) because he defining symbols and concepts as tools for mental activity which may be constructed from external sources. As a matter of fact, distinguishing between sensations and concepts originates from scholastic philosophy. The Vygotskian perspective is interesting because he sees symbols and concepts as tools as mediators in the social world in the same way that we have physical tools as mediators in the concrete world. In addition to Peirce and Vygotski, it was probably Raymond Lull who drew a difference between intentio prima (sensation) and intentio secunda (concept) for the first time. In this paper, we shall concentrate on the latter notion combining it with the Vygotskian idea of symbols and concepts as tools for mental activity.

2.3 Intentions as perspectives

One goal of this paper is to introduce a framework, within which an intention is interpreted as being a "perspective" that consists of an intension (of some concept, proposition, or structure as *tools* and *non-psychical material* for the activity) and a conceptual scheme (composed of some interrelated concepts, propositions, or structures). The following assumptions are meant to serve for a more detailed analysis of this framework.

- A particular intension of some concept/symbol is the same mental representation as the connotation of the corresponding term.
- To be intentional, a representation must include an intension connected to some conceptual sub-models or other *symbolic structures*.
- These conceptual sub-models are what Peirce called "interpretants" and Vygotsky as *symbols* and tools to conceptualize our world outside us.
- The constituents of conceptual sub-models are model constructs. These include such entities as concepts, propositions, and structures. From the Vygotskian viewpoint, we may see it from the level of symbolism.
- The most important species of concepts are model concepts (i.e. basic concepts, or categories) which generate connections between different conceptual sub-models. These sub-models may also be categorized as key symbols and primary tools for the intended activity.
- Model concepts form the kernel of conceptual models consisting of different conceptual sub-models.

3. ARCHITECTURE OF ROBO-ELC

Robo-eLC, which embeds state of the art technology with a Multimodal Interface (MI), is a combination of various pieces of hardware and software; therefore, to understand its multimodal interfaced system, it is important first to describe its constituent parts. The MI uses hypermedia and combines learning technologies (Naidu, 2002) and robotics into an interactive learning appliance for affecting learning attitudes.

The MI's purpose is to simplify the comprehension and acquisition of complex data. As some studies have highlighted (Matti, 2002), differences in mental and cultural attitudes have an influence on the quality of the perception of messages and the comprehension of rapidly flowing information. Hence the main role of the MI is to aid users in grasping ideas and concepts related to unfamiliar situations. During the use of the multimodal interface, the attention and interest of users was kept alive by the MI influencing users focus on relevant facts and by the MI correctly dosing tailored amounts of information.

The human-like robot, which looks like a poorly-dressed woman (see Figure 1) gets the attention of passers-by through its physical presence and then initiates interaction with passers-by. The choice to have a woman-robot was the consequence of various facts; among which, the most relevant was that in developing countries women are the most needy, as described in the reports of De Haan "Poverty in Emerging Asia: Progress and Setback" and Hulme "Chronic poverty: meanings and analytical frameworks". In addition Robo-eLC intends to portray real-life situations of women in poor countries, supporting the view of some according which women should be recognized as representative of the deepest needy in developing countries (Harcourt, 2001).

3.1 The Multimodal interface

The MI is made up of three components that cooperate directly or indirectly together. These components are the *visual interface*, the *audio system* and the *motion system*.

Users begin their interaction through the visual interface (a touch screen). Users are exposed to an organised set of screens where they receive information on what to do in the existing phase and how to proceed to the following phases. Phase by phase, users acquire knowledge and get confidence in using the system.

Figure 1. Robo-eLC in function

The robot counts the time between each user action and, then, acts accordingly. Through the inputs received via the touch screen, the robot can follow the behaviour of users and verbally interact in a realistic way through the audio or aural components. The verbalizations of the robot provide information to the users. This information can be related to the specific browsing action or related to the donation. Robo-eLC keeps track of the flow of time and gently reminds users to complete their interaction in a reasonable amount of time.

Users perceive what the robot does and says as an incentive to interact with the system and reach a conclusion (usually a donation). The movements and speech of the robot are synchronized. The two elements were synchronised by time-counting events that were dependent on users' actions. Depending on the user's actions, or lack of action, the robot would move or say something to help, advise, or stimulate the user through the learning and donation process. The *motion component* of the MI contributes to the realistic element of the robotic learning environment. During an evaluation of Robo-eLC at a fund raising event in 2003, we noticed that users got excited about the lifelike motions of the robot. Some of the users mentioned that the overall impression was that Robo-eLC seemed "almost" human.

The three physical components of the MI (i.e., motion, speech, and hearing) are integrated with a fourth element - the cognitive element. By "cognitive element" we refer here to the condition in which most of the users had high levels of mental activity. This was a Robo-eLC generated condition where users were able to quickly make decisions. The condition was the result of a combination of the first three elements of the multimodal interface and the learning module. It is important to underline that this condition does not refer to the cognitive process itself, but instead to the psychological environment generated by Robo-eLC that stimulates users' activity. Without this fourth component, the MI of Robo-eLC would fail to reach its stated goals.

3.2 Architectural elements of Robo-eLC

Robo-eLC's architectural elements are the touch screen, the motors, the micro controller, the sound card and the speakers, the bankcard reader, the printer, and the software.

The touch screen is the platform for interface that allows interaction between users and Robo-eLC. Users select functions according to the information that appears on the screen and, consequently, the robot responds accordingly and provides information in visual, aural, and kinetic forms. Robo-eLC coordinates its own gestures and verbalizations.

The robot uses servomotors to move the parts of its body. All motions are three-dimensional and are obtained by coupling two servomotors per body part. Servomotors are controlled by a programmable microchip. The micro controller, which it is connected via a computer's serial port, is controlled by software,. In short, the software commands the micro controller that interprets the orders that are sent to the servomotors.

The sound card and loudspeakers enable the robot to provide aural feedback to users. The "talkative" aspect combined with the ability to move contributes to the perceived humanness of robot. The loudspeakers are protected by metal nets and located in the chest to bring the voice of the robot as close as possible to the head.

The printer creates a receipt with the information of the money operations that have occurred. Personalized information can be recorded on the receipt as well.

The software simultaneously controls the motors, the speech, the e-learning module, and responds to the user's activities on the touch screen so that the robotic behaviour appears human-like. The learning module, managed by the software, is designed to take the cultural background in which the Robo-eLC is intended to operate into consideration. Text and vocal messages target culturally specific elements to bridge the cultural gaps between users and the inhabitants of the targeted countries.

3.3 The e-learning module

The e-learning module consists of two parts: an *internal component* and an *external component*. The *internal component* is active during the interactive process and it works as an empathic reminder about the value of what impact the users' actions might have in the target country. This internal e-learning module presents some of the cultural features of the target countries and concretises vivid pictures of daily life. One of the practical purposes of Robo-eLC is to get users to contribute. It is very important to increase users' understanding of the actual impact of their contributions. For this motive, the donation perception must not be of an abstract nature but must be understood in terms of the real needs of real people. At the end of the donation process, counters show to users what amounts of money have been donated at particular times for the specific target countries.

The *external component* of the e-learning module is located on the web and it can be used to inform people about Robo-eLC concept, its development, and history. Robo-eLC can guide users to specific web pages to allow a better understanding of the target countries and their cultural elements. These web pages can store and show statistical information about the use of the robot. The pages can also show detailed information on the target countries and those other aspects that might be relevant for Robo-eLC users. Statistical and real-time information on donations and existing needs can be put in web pages to increase the interest of users to follow-up events and eventually return to donate.

4. ANALYSIS OF FEEDBACK

Various processes have been programmed into the Robo-eLC with the purpose to keep users' interests high and to aid them in making well thought out decisions. One of the main goals of the LMI is to provide users with the help needed to resolve their uncertainty to donate during the transaction process and to give advice and reminders. This is achieved via MI screen shots (the graphic interface), vocal assistance, and robotic motions. Users are informed of the accessibility of other information that is made available in web addresses (*external component* of the learning module).

The Robo-eLC was tested in June 2003 in Joensuu (Finland) at an info and fund raising event organized to bring attention to the needs of developing countries. Thousands of people participated in the event and many of them tested Robo-eLC discovering, to their own surprise, that they could enjoy while learning and donating. A state of excitation was noticed in many users of the appliance because of their perceiving the robot as "almost" a human being. In some cases there were signs of "robotic-addiction" where people returned to use the appliance just because of the pleasure they got from it.

The multimodal interface along with the learning module constitutes the Learning Appliance (La Russa, 2003). The speech, motion and screen phases are synchronized so that users' interactions with Robo-eLC generate specific coordinated robotic behaviors. Robo-eLC interventions (involving robot speech, action, screen shots, or other operations) are based on user behaviors. The hardware has been reported to have a strong impact as a silent communicative tool.

The verbalizations of the robot and the learning phases are "synchronised" so that any robot-counted delay can be attributed to a specific user behaviour. The timing of the operations of the robot (speech, movement, screen shots etc.) and user behaviour have been pre-calculated and set in the software of Robo-eLC. The desired result is that users never feel like they are in the donation process alone even though they are dealing with an appliance. Users are stimulated by the Robo-eLC to discover, in a constructionist way (Papert,1991; La Russa, 2003), the excitement of finding out something new while at the same time giving them the correct perception of being needed and useful. At the end of the last learning phase, users are ready and cognitively supported to make a money transfer.

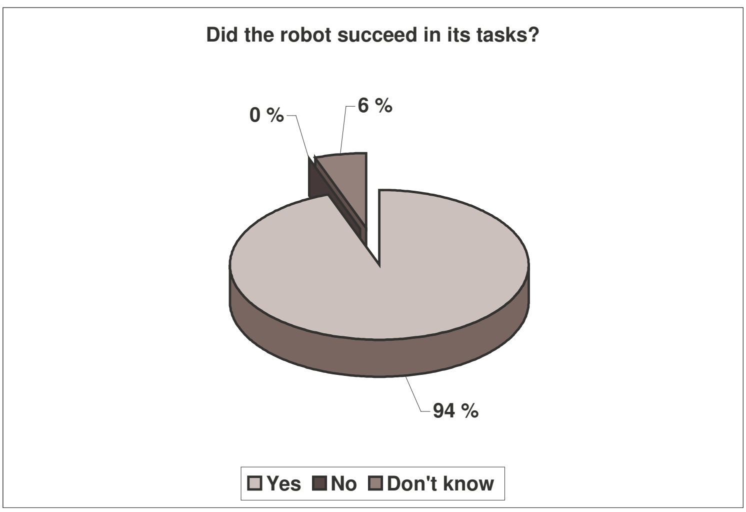

Figure 2. Analysis on Robo-eLC learning and cognitive aiding feature

While users are directed to focus on relevant facts and correctly dosed amounts of information, they are also left the freedom to investigate and discover information that they consider useful to themselves. They can access the external component of the e-learning module, for a limited time, and look for information on predetermined web pages. Providing web-based services and information are fundamental for promoting users' sense of openness and freedom to choose and create their own knowledge. Some of these behavioural elements are also described in the "Theory of Planned Behaviour" of Schifter & Ajzen.

Throughout the process of using Robo-eLC users are encouraged to construct new ideas and create rapid patterns. The consequence of this is that users want to know more and repeat their positive experience as described in Pritchett (2002) and as it was in our test cases.

Users that had completed their operations with the robot were asked to provide feedback to the researchers by filling out pre-made forms. They were asked to express, for analysis reasons, their impressions about the Robo-eLC and its functionalities. The information that was obtained is related to the functionalities and the influences that the Robo-eLC had on users via its multimodal interface. The majority (94%) of the 50 users' assessments regarding the successfulness of the robot and its interface as a learning and cognitive aiding tool was clearly positive (Figure 2). Three users (6%) could not express any opinion but nobody had a negative remark.

5. CONCLUSIONS AND FUTURE WORKS

The learning multimodal interface created in the Robo-eLC influences users' behavior by stimulating their cognitive processes. The properly combined elements of computer science, education, sociology, engineering, and cognitive science have been used to increase the amount of information and data that can be transmitted to and acquired by users. The learning multimodal interface is a suitable communication system to the generic user of the Robo-eLC. The comprehension and acquisition of information and data is improved through the use of a stimulating cognitive element. Users rapidly learn and can appreciate the pleasure of rediscovering thanks to the ability to construct of their own learning environments. A sense of freedom to navigate is guaranteed by both the internal learning component and the external one. Quickly learning, not only data, but ethical values, which in our test case corresponds to the perception and endorsement of an active role in global economic inequity, is an encouraging platform to base new forms of education on.

In the near future, we intend to implement a management system that would allow full control of the Robo-eLC functionalities without the need for expertise in computer science. Modifying features, learning modules, and even the robotic behaviour will be an easy task for anyone. This will open plenty of opportunities for those that wish to use the Robo-eLC learning appliances in completely new educational manners.

Concerning the multimodal interface, we are going to explore the opportunity to improve the robot by adding the capacity to hear and understand directly from human speech. A movement recognition system should be also implemented to allow the robot to identify the location of users. In addition to studies to be conducted on the creation of learning modules (for example by use of Learning Objects' theories), the above-described technical innovation should increase the quality of the creative cognitive environment that Robo-eLC can create.

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Appendices

Appendix A

User Feedback form (original Finnish version)

Joensuun Yliopisto
Turun Osuuspankki
Lounais-Suomen Syöpäyhdistys Ry
Helmikuu 2004

KYSELYLOMAKE
Vaivais€ukko

JOENSUUN YLIOPISTO

Taustatietoja

Ympyröi sopiva vaihtoehto

Sukupuoli	nainen	mies
	☐	☐

Ikä	-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Arvioi seuraavia väittämiä käyttäen asteikkoa 1-5 (missä 1 = täysin eri mieltä , 2 = jokseenkin eri mieltä , 3 = en osaa sanoa, 4 = jokseenkin samaa mieltä, 5 = täysin samaa mieltä).

1. Vaivais€ukon toiminta

	1	*2*	*3*	*4*	*5*
Vaivais€ukko käyttöliittymä oli helppokäyttöinen	☐	☐	☐	☐	☐
Vaivais€ukon toiminta oli johdonmukaista	☐	☐	☐	☐	☐
Lahjoituksen tekeminen Vaivais€ukon avulla oli vaivatonta	☐	☐	☐	☐	☐
Vaivais€ukon käyttö oli hauskaa	☐	☐	☐	☐	☐
Pankkikortilla lahjoittaminen oli helppoa	☐	☐	☐	☐	☐
Pankkikortilla lajoittaminen oli hyvä valinta	☐	☐	☐	☐	☐
Annetut ohjeet olivat selkeät	☐	☐	☐	☐	☐

2. Vaikuttaminen

	1	*2*	*3*	*4*	*5*
Vaivais€ukko vaikutti lahjoituspäätökseen	☐	☐	☐	☐	☐
Vaivais€ukon materiaalilla oli vaikutusta lahjoitusmäärään	☐	☐	☐	☐	☐
Vaivais€ukko on parempi kuin Vaivaisukko	☐	☐	☐	☐	☐
Lahjoituskohteet olivat sopivia	☐	☐	☐	☐	☐

3. Arvioi seuraavia väittämiä.

	Ei	*En osaa sanoa*	*Kyllä*
Vaivais€ukko vaikutti merkittävästi lahjoituspäätökseen	☐	☐	☐
Epäröitkö lahjoittaa Vaivais€ukon avulla?	☐	☐	☐
Oliko Vaivais€ukon informaation tärkeää?	☐	☐	☐
Oliko siitä hyötyä, että Vaivais€ukkossa oli konkreettisia esimerkkejä siitä mitä lahjoituksellani tehdään?	☐	☐	☐
Onnistuiko Vaivais€ukko tehtävässään?	☐	☐	☐

4. Sähköinen raha ja Vaivais€ukko

	1	*2*	*3*	*4*	*5*
Vaivais€ukkon avulla tuntui helpolta lahjoittaa pieni rahasumma	☐	☐	☐	☐	☐
Vaivais€ukko olisi parempi jos se tunnistaisi minut ja tapani käyttää sitä	☐	☐	☐	☐	☐
Vaivais€ukko olisi parempi jos siinä olisi toiminto, joka ymmärtäisi tapani käyttää rahaa ja toimisi sen mukaisesti kun käytän sitä uudelleen.	☐	☐	☐	☐	☐
Vaivais€ukkoa voitaisiin käyttää myös muun laisiin sähköisiin asiointitarkoituksiin (laskujen maksu, pikkuostosten maksaminen)	☐	☐	☐	☐	☐

Palautetta ja kehittämisideoita voit kirjoittaa lomakkeen takapuolelle.

Kiitos vastauksestasi!

Kysely liittyy Gaetano La Russa Joensuun yliopistolle tekemään tutkimukseen.
Yhteystiedot: larussa@cs.joensuu.fi

User Feedback form (English translation)

Joensuun Yliopisto
Turun Osuuspankki
Lounais-Suomen Sydänyhdistys Ry
Helmikuu 2004

Questionnaire Form
Vaivais€ukko

JOENSUUN YLIOPISTO

Background Information

Please mark your answer choice

Gender	female	male
	☐	☐

Age	-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Evaluate according the values 1-5 (where 1 = I completely disagree, 2 = I partially disagree, 3 = I am unsure, 4 = I partially agree, 5 = I completely agree).

1. Functionality of the robot

	1	*2*	*3*	*4*	*5*
User interface was easy to use	☐	☐	☐	☐	☐
The use of the robot was consistent	☐	☐	☐	☐	☐
Donating was simple	☐	☐	☐	☐	☐
Donating was fun	☐	☐	☐	☐	☐
Using bankcard was easy	☐	☐	☐	☐	☐
The use of bankcard was a good choice	☐	☐	☐	☐	☐
Instructions were clear	☐	☐	☐	☐	☐

2. Impacts

	1	*2*	*3*	*4*	*5*
The robot had an impact on the decision to donate	☐	☐	☐	☐	☐
The learning material had an impact on the chosen target	☐	☐	☐	☐	☐
The robot is better than a static/traditional collecting system	☐	☐	☐	☐	☐
The list of targets were adequate	☐	☐	☐	☐	☐

3. Evaluation on following statements

	No	*I am unsure*	*Yes*
Did the robot influence considerably the decision to donate?	☐	☐	☐
Did you hesitate to donate with the robot?	☐	☐	☐
Was the information provided by the robot important?	☐	☐	☐
Was it useful to show the concrete achievements that donation would obtain?	☐	☐	☐
Did the robot succeed in its tasks?	☐	☐	☐

4. e-Commerce application and Vaivais€ukko

	1	*2*	*3*	*4*	*5*
With the help of the robot it was easy to donate small amounts	☐	☐	☐	☐	☐
It would be better if the robot would recognise me and remember my actions	☐	☐	☐	☐	☐
The robot would be better if it would understand my use of money and accordingly help me next time	☐	☐	☐	☐	☐
The robot could be used in other e-commerce applications	☐	☐	☐	☐	☐

For suggestions and development ideas you can write on the back side of this form.

Thank you for answering!

This questionnaire is part of Gaetano La Russa research in the School of Computing of Joensuu
Contact details: larussa@cs.joensuu.fi

Appendix B

User Behaviour Form

Joensuun Yliopisto
Suomen Lähetysseura ja Noljakan Kirkko
Joulukuu 2007

Questionnaire Form
InfoKioski

JOENSUUN YLIOPISTO

User behaviour

Tick the proper box

Gender	female	male
	☐	☐

Age	-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

The following values are to be used: 1 = absent , 2 = low , 3 = average, 4 = substantial, 5 = full

1. User interaction with the physical environment

	1	*2*	*3*	*4*	*5*
Presence of other potential users (1=0, 2=1, 3=2-3, 4=<5, 5=>5)	☐	☐	☐	☐	☐
User verbal contact with other people	☐	☐	☐	☐	☐
User visual contact with other people (i.e. looking/watching)	☐	☐	☐	☐	☐
User touch contact with other people	☐	☐	☐	☐	☐
Noise level (related to similar standard public places)	☐	☐	☐	☐	☐
Light level (considering the external light contributions)	☐	☐	☐	☐	☐
Appreciation for the amenity of the location of the InfoKiosk	☐	☐	☐	☐	☐

2. User perception of the InfoKiosk

	1	*2*	*3*	*4*	*5*
Surprise	☐	☐	☐	☐	☐
Curiosity	☐	☐	☐	☐	☐
Uncertainity	☐	☐	☐	☐	☐
Investigative	☐	☐	☐	☐	☐
Confidential	☐	☐	☐	☐	☐

3. User emotional expressions

	1	*2*	*3*	*4*	*5*
Verbal positive comments (1=absent, 5=entusiastic)	☐	☐	☐	☐	☐
Verbal negative comments (1=absent, 5=aversion)	☐	☐	☐	☐	☐
Facial positive expressions (1=absent, 5=entusiastic)	☐	☐	☐	☐	☐
Facial negative comments (1=absent, 5=aversion)	☐	☐	☐	☐	☐
Overall positive expressivity (1=absent, 5= entusiastic)	☐	☐	☐	☐	☐
Overall negative expressivity (1=absent, 5=aversion)	☐	☐	☐	☐	☐

4. User's behavior during the interaction with the InfoKiosk

	No	*Yes*	*Neither*
Positive and constructive	☐	☐	☐
Increasingly participative	☐	☐	☐
Impressed	☐	☐	☐
Confused	☐	☐	☐
Motivated	☐	☐	☐
Frustrated	☐	☐	☐
Donative	☐	☐	☐

Kysely liittyy Gaetano La Russa Joensuun yliopistolle tekemään tutkimukseen.
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Appendix C

Event Observation Schema Form

InfoKiosk test cases in Noljakka, February 2008

Event (shot description):

Date:	Approx number of participants: Approx age compositions (children %): Adults: 1) young 2) middle-age 3) elderly

Concise description of people's behavior:
(where they stay, how they interact within themselves and what is the interest on the machine and its functions)

Short comments of the observer:

Description of the location of the machine:

Gaetano La Russa

Towards an Understanding of Humanoid Robots in eLC Applications

This work is the outcome of interdisciplinary research in the field of human-robot interaction and human behaviour in the usability sector of fundraising. Basic rules are analysed which govern the design of effective fundraising robots in given physical environments and cultural background which then, in turn, promote enhanced and pleasant interactions. The scientific contribution of this work is a set of specifications to be used in the design and further development of fund raising robots.

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